Check List the journal of biodiversity data
ANNOTATED LIST OF SPECIES

An annotated checklist of the lichen biodiversity at two Mars analog sites: The Mars Desert Research Station (Utah, USA) and The Flashline Mars Arctic Research Station (Nunavut, Canada) recorded during the Mars 160 Mission

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Abstract. During the Mars 160 Mission in 2016 and 2017, crews at the Mars Desert Research Station (MDRS) in Utah, USA and the Flashline Mars Arctic Research Station (FMARS) on Tallurutit (Devon Island), Nunavut, Canada, conducted a collections-based survey of lichen biodiversity at each of these Martian planetary analogs. Here we present the results of these studies as two annotated checklists, including 35 lichen species from MDRS and 13 species from FMARS, alongside details on the distribution of these species, relevant taxonomic notes, and photos of each species as an identification aid. This work adds to our knowledge of the biodiversity of these unique sites and provides an important baseline for future analog research at these stations.

Key words. Devon Island, Floristics, Haughton Crater, Mars Society, Planetary Analog, San Rafael Swell

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INTRODUCTION

"And at this conference there had been no strong attempt to organize the posters into hallways by subject matter, so the 'Distribution of Rhizocarpon geographicum *in the East Charitum Montes' detailing the high-altitude fortunes of a crustose lichen that could live up to four thousand years, was facing 'Origins of Graupel Snow in Saline Particulates Found in Cirrus, Altostratus, and Altocumulus clouds in Cyclonic Vortexes in North Tharsis,' a meteorological study of some importance."*

Kim Stanley Robinson — *Green Mars*

In many ways lichens make better astronauts than humans do. They are ecologically important in the desert environments selected as Mars planetary analogs due to their resistance to UV radiation and desiccation (Armstrong 2017). Some species are even able to survive exposure to space (Sancho et al. 2007) and to simulated Martian environments (de Vera et al. 2019; Meeßen et al. 2015). These composite organisms, primarily comprised of a mycobiont (fungus) and an alga or cyanobacterium (photobiont), are found in nearly every terrestrial habitat on the planet (Lutzoni and Miadlikowska 2009). While some lichen species have more general habitat requirements, many lichens have diversified to fill specific niches (Manzitto-Tripp et al. 2022), and those taxa possessing microscopic ascospores can be found quickly expanding in favorable habitats due to short-distance dispersal in atmospheric currents (Favero-Longo et al. 2014). Understanding

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lichen biology and patterns of biodiversity can contribute to both biological sciences here on Earth, and also our knowledge of these important astrobiology test organisms, and perhaps how they could be useful one day on Mars (Oliveira and Maciel-Silva 2022).

The Flashline Mars Arctic Research Station (FMARS) at Haughton Crater, Tallurutit (Devon Island), Nunavut, and its counterpart, the Mars Desert Research Station (MDRS) in southern Utah, are simulated Mars outposts situated at two well-known Martian planetary analogs: environments that are geologically and environmental similar to the solar system's fourth planet from the sun (Osburg 2003). Owned and operated by The Mars Society, these stations host researchers learning how to live and work on Mars. Crews conduct research programs on everything from testing new rovers to isolating local microbes; these astrobiology simulations are a particularly important dress-rehearsal in the search for potential life on Mars (Direito et al. 2011). These studies rely on comprehensive knowledge of the local biota, making traditional natural history surveys (e.g., Sokoloff et al. 2016; Sokoloff et al. 2020) important precursors to these simulated missions.

At both stations, lichens are conspicuous members of the local biota, often encountered by crew members studying the geology and microbiology of the exploration areas surrounding the two sites. They grow on rock, soil, and living substrates (like mosses and trees), and exchange their photosynthetic partners with endolithic colonies of algae and biological soil crusts, in the process altering their substrate (Sokoloff et al. 2016). Due to these characteristics, and their relatively conspicuous nature, the search for lichens could be an excellent terrestrial analog for training crews at these stations in the search for biomarkers on Mars, while also advancing knowledge on the biodiversity and ecology of these long-term research sites, useful information for astrobiology-focused simulations and land management programs.

During the Mars 160 Mission, a twin mission to both MDRS and FMARS sponsored by The Mars Society in 2016 and 2017, respectively, we carried out a collections-based survey of lichen biodiversity at both stations. Previous surveys have recorded 182 lichen species from the Truelove Lowlands on Devon Island (Barrett and Thomsen 1975), 61 species from eastern Wayne and Emery counties, Utah (St. Clair et al. 1991; Newberry et al. 1991; St. Clair et al. 1995; Rajvanshi et al. 1998; Sokoloff et al. 2016) and 16 species from the vicinity of MDRS (Sokoloff et al. 2016). This current study is intended to add new species occurrence knowledge for both stations; this will contribute valuable information on lichen biodiversity to earthbound scientists while simultaneously giving the crew the opportunity to develop the astrobiological techniques that will be needed by future Martian explorers.

STUDY AREAS

The Mars Desert Research Station is located in Wayne County, Utah, USA at 38°24′23″N, 110°47′31″W. Located in the deserts south of the San Rafael Swell, the local geology is dominated by Mancos Shale and the sandstones of the Morrison Formation (Figure 1A) (Direito et al. 2011), with numerous microhabitats containing a diverse array of vegetation, including endemic species found nowhere else. Common vascular plant species in habitats near MDRS include *Atriplex gardneri* var. *cuneata* (A.Nelson) S.L.Welsh, *Ericameria nauseosa* (Pall. ex Pursh) G.L.Nesom & G.I.Baird, *Ephedra viridis* Colville, and *Eriocoma hymenoides* (Roem. & Schult.) Rydb; see Sokoloff et al. (2016; 2020) for a synopsis of local habitats, as well as common and endemic species. Annual precipitation based on a 56-year average has been measured at 141.22 mm in nearby Hanksville, with hot summers and cool winters (Clarke and Stoker 2011).

At eleven collection sites in Utah, the collection team included crew geologists who were able to describe the substrate ecology and superficial geology of the following locations around the Mars Desert Research Station.

"Shannon's Rock Garden" (informal name, 38°24′10″N, 110°47′13″W; 1,370 m), consists of outcrops of near-horizontal, light-coloured medium to coarse sandstone of the Brushy Basin Member of the Jurassic Morrison Formation (Clarke and Stoker 2011, Clarke et al. 2020). These outcrops were part of a semi-exhumed paleochannel, where paleocurrent flow was to the northeast.

"Hab Ridge", immediately west of the station (informal name, 38°24′40″N, 110°47′44″W; 1,410 m), consists of long exposures of the Cretaceous Dakota Sandstone. The outcrop consists of near-horizontal, large, massive slabs of medium-grained slightly calcareous sandstones. The Dakota sandstone was deposited in a marginal marine environment with large tidal channels (Ulicny 1999). The sandstone is heavily bioturbated with horizontal, vertical, and branching burrows.

At "Galileo Road" (informal name, 38°25′00″N, 110°46′19″W; 1,400 m), there is an exhumed and inverted channel within the Brushy Basin Member of the Jurassic Morrison Formation (Clarke and Stoker 2011, Clarke et al. 2020). The channel was composed of cross-bedded gravelly sandstone to conglomerate.

At an unnamed canyon between Tank Wash and the junction of Bureau of Land Management (BLM) roads 1572/1575, 3 km north of the MDRS Hab (38°26′02″N, 110°47′43″W; 1,370 m), there is a dry waterfall formed by an antecedent stream cutting through a ridge formed by an exhumed and inverted paleochannel within Brushy Basin Member of the Morrison Formation. The paleochannel flowed in a northeastern direction. The paleochannel is here composed of fine to coarse sandstone, and locally contains pebbles. The sandstone that forms the cap of the dry waterfall is strongly undercut and has a substantial plunge pool at its foot. This may contain water from the last flow.

Figure 1. A. The Mars Desert Research Station in Utah, USA, surrounded by Mancos Shale and Dakota Sandstone deserts. **B.** Two crew members collecting samples wearing simulated spacesuits near the Flashline Mars Arctic Research Station on Tallurutit (Devon Island), Nunavut.

Adjacent to the cattle grid at the beginning of Cow Dung Road (38°22′12″N, 110°46′04″W; 1,350 m) there is a remnant gravel terrace of the Fremont River. The deposit is up to 2 m thick in exposures along the road cut on the north side. The gravels are composed of well-rounded 2-15 cm clasts. They are made up of mostly igneous lithologies, predominantly diorites and dacites from the nearby Henry Mountains, basalts from the "Aquarius plateau", and quartz. They were deposited during the Pleistocene and are probably 80-90,000 years old. Basalts are estimated to contain 40-50% SiO2, diorites 50-60% SiO2, and dacites >60% SiO2 . Chert, chert and sandstone, jasper, limestone quartzite, and conglomerate are minor lithologies at this site.

A box canyon in a quarry (38°22′17″N, 110°45′04″W; 1,370 m) is one of many formed by the erosion of the thinly bedded mudstones and gypsum of the Summerville Formation, the thin green gypsum-rich Tidwell Member of the Morrison Formation (Petersen 1980) is capped by the resistant sandstones of the Salt Wash Member of the Morrison Formation (Clarke and Stoker 2011).

East of the Mars Desert Research Station (38°24′13″N, 110°47′13″W; 1,380 m) is a site consisting of numerous sandstone outcrops associated with a north flowing exhumed paleochannel within the Brushy Basin Member of the Morrison Formation. This is almost certainly the same paleochannel as "Shannon's Rock Garden". The sandstone varies from fine to coarse in grainsize, and locally contains pebbles.

At "Cactus Road" (informal name, 38°24′35″N, 110°46′22″W; 1,370 m) the collection site is on the south side of the track to "Green Mars" (informal name). It consists of an undulating surface of partially vegetated former aeolian sand, mantled by 1-4 cm rounded pebbles that form a lag of about 30% coverage. Most of these were composed of quartzite with minor quartz, chert, and jasper. The site has been eroding rather than accumulating aeolian sediment and the pebbles are interpreted as a lag. However, erosion rates are slow as indicated by the absence of well-developed erosional pedestals.

The "Valley of the Stars" (informal name, 38°29′59″N, 110°55′32″W; 1,360 m) occurs in a valley between two ridges of sandstone and floored by weathered shale. Stratigraphically the valley occurs within the

Mancos Shale, the sandstone being composed of the Ferron Member and the shale the Tununk Member (Clarke and Stoker 2011). The sandstone is fine to medium-grained and well sorted. It is interpreted as being deposited in a deltaic environment. The surface of the sandstone, both outcrop and boulders, has been subjected to honeycomb and cavernous weathering, both appear to be ongoing.

The "Ruined House" (informal name, 38°24′16″N, 110°46′55″W; 1,380 m) is a small butte of conglomeratic cross-bedded sandstone to sandy conglomerate. The conglomerate represents an exhumed and inverted channel within the Brushy Basin Member of the Morrison Formation (Clarke and Stoker 2011, Clarke et al. 2020). Isolated dinosaur bones are found near the top of the butte. Paleocurrent flow direction was to the north. Boulders of conglomeratic cross-bedded sandstone to sandy conglomerate have fallen from the side of the butte form a talus over mudstones of the Brushy Basin Member.

The collecting site at "Kissing Camel Ridge" (informal name, 38°23′34″N, 110°47′09″W; 1,360 m) is about 30 m east of the road on the north side of the ridge. The ridge is formed by an exhumed and inverted paleochannel of conglomeratic sandstone to conglomerate within the Brushy Basin Member of the Morrison Formation. The paleochannel flowed east. The coarse-grained, cross-bedded clastics form a cap to the more easily eroded shales of the Member. In this particular location, much of cap rock has been eroded away, sliding and/or rolling down to form a talus at the foot of the slope composed of the mudstones of the Brushy Basin Member.

The Flashline Mars Arctic Research Station is located on Tallurutit (Devon Island), in the Qikiqtaaluk Region of Nunavut, Canada at 75°25′52″N, 089°49′27″W. On the rim of the Haughton Impact structure, the station is situated in a periglacial setting on carbonate shattered limestone outside of the impact breccias of the crater (Grieve 1988). Annual precipitation is low (under 13 mm) with cold winters and cool summers (Lee and Osinski 2005). As in other nearby sites within the limestone of the central Canadian Arctic Archipelago, vascular plant diversity is relatively low (Schofield and Cody 1955). Common vascular plant species collected by the crew in 2017 included *Draba corymbosa* R.Br. ex DC., *Dryas integrifolia* Vahl. subsp. *integrifolia*, *Papaver cornwallisense* D.Löve, *Saxifraga cespitosa* L., and S*axifraga oppositifolia* L.

At FMARS, lichens were collected on EVAs (Figure 1B) at four general locations, mapped against the geology of the crater as described in Osinski et al (2005).

Lichens gathered in and around the Flashline Mars Arctic Research Station to the immediate northwest of Haughton crater from July 20-26 were collected on Dolostone from the Upper Member of the Allen Bay Formation.

Immediately east of the crater, along the upper lip of the impact structure (Eastern rim of Haughton Impact Crater), lichens gathered on July 29 were collected on Dolostone from the Lower Member of the Allen Bay Formation.

Further east along the Haughton Crater rim, on July 30, the team collected on Dolostone impact breccia.

Lastly, in the northern half of the Haughton Impact Crater, lichens collected on August 1 were collected on dolostone of the Bay Fiord Formation and impact melt breccia respectively.

METHODS

During both phases of the Mars 160 Mission (Knightly et al. 2018) lichens were collected on simulated extravehicular activities (EVAs), by crew members dressed in simulated spacesuits and following similar operational constraints that they would on the surface of Mars. Specimens were collected primarily by Anushree Srivastava and Yusuke Murakami (as noted in the collection numbers in the annotated checklists) with support from all other members of the Mars 160 crew. In the annotated checklists, Srivastava numbers follow the format AS** (in Utah) and DI** (in Nunavut); Murakami collection numbers follow the format YM**-**-**.

During the Mars Desert 80, the first half of the mission at the Mars Desert Research Station in Utah from September 24th to December 13th, 2016, lichens were collected at 29 sites (Figure 2) in Wayne and Emery counties (the "Valley of the Stars" site straddles the boundary between these two counties).

The Mars Arctic 80—originally conceived as a longer, 80-day mission, took place between July 17th and August 16th, 2017, at the Flashline Mars Arctic Research Station on Tallurutit (Devon Island), in Nunavut. There, the crew collected lichens from 17 sites near the station and across Haughton Crater (Figure 2). This research was licensed under the following permissions: Nunavut Water Board License 8WLC-LHA1718, Nunavut Research Institute License 02 031 17R, Nunavut Department of Wildlife Research Permit 2017-046, and Qikiqtani Inuit Association Certificate of Exemption Q17X014.

Lichen collection sites were determined by the crew in consultation with The Mars Society mission directors during the mission to encompass as many microhabitats and geological substrates as possible. At each site, the crew searched the area using an "intelligent meander" (Selva 2003) to collect a representative sample of each lichen species present in each location. Specimens were collected along with standard herbarium label data and dried in paper bags. At eleven locations in Utah and four locations in Nunavut, crew geologists described the substrate ecology and habitat described in the site descriptions above and the results below.

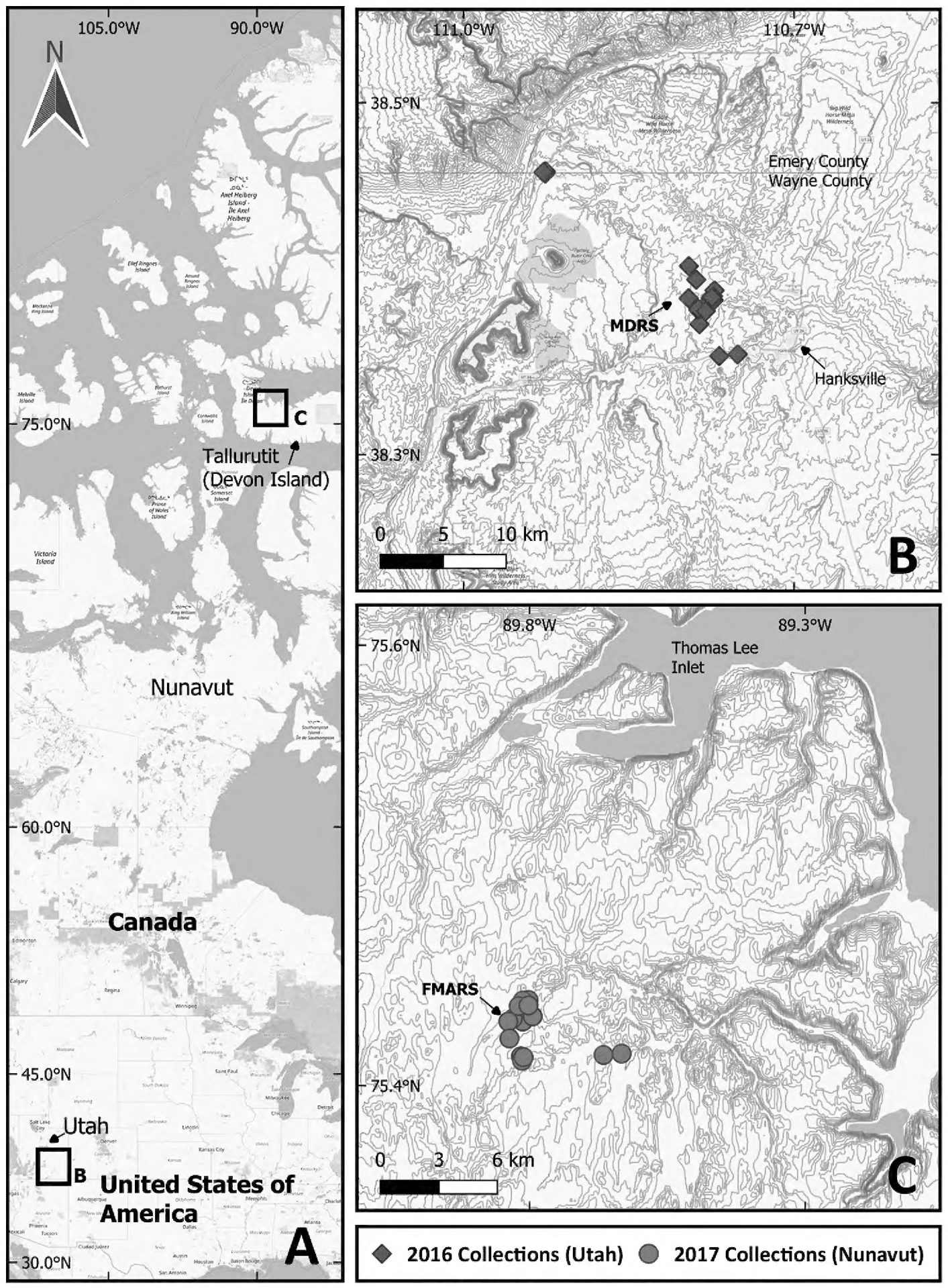

Figure 2. Study areas. **A.** Mars Society analog stations in the United States of America (Utah), and Canada (Nunavut), locations of insets B and C indicated. **B.** Lichen collection locations for 2016 in the vicinity of the Mars Desert Research Station, Utah. **C.** Lichen collection locations for 2017 in the vicinity of the Flashline Mars Arctic Research Station on Tallurutit (Devon Island), Nunavut. Map data via QGIS and OpenStreetMap.

Specimen identification involved examination of overall morphology and apothecial/perithecial sections to examine ascospores, following protocols in Brodo et al. (2001). Where necessary, spot tests and thin layer chromatography were used to investigate lichen chemistry, following protocols in Culberson and Kristinsson (1970) and Orange et al. (2001). For a subset of material, ITS DNA barcodes were used to confirm species identifications, following protocols in Ratnasingham and Hebert (2007). Dichotomous keys in Lichen Flora of the Greater Sonoran Desert Region, Volumes 1-3 (Nash et al. 2002; 2004; 2007) and American Arctic Lichens (Thomson 1984; 1997) were used for the identification of material from Utah and Nunavut, respectively. Additionally, various literature sources were used during identification to ensure accuracy of species concepts and up to date nomenclature. These primary sources, where used, are cited in the checklists below. The identified specimens have been deposited at the National Herbarium of Canada (CANL) at the Canadian Museum of Nature; CANL barcodes are cited in the annotated checklists below.

RESULTS

Of the 151 specimens collected in 2016 and 2017, 23 were discarded as they were too immature or small for accurate identification. These included 21 specimens from MDRS in Utah with the following collection numbers: Srivastava AS01, AS07, AS10, AS11, AS17, AS38, AS50, AS58, AS59, AS61, AS62, AS63, AS64, AS67, AS74, AS78, Murakami YM-27-03, YM-27-04, YM-27-05-02, YM-38-01-01, YM-38-01-02. Two specimens from

Table 1. Lichen species collected at the Mars Desert Research Station (Utah, USA) in 2014 (treated in Sokoloff et al. 2016) and 2016.

Family	Species	Year collected
Acarosporaceae	*Acarospora fuscata* (Schrad.) Arnold	2016
	Acarospora obpallens (Nyl) Zahlbr.	2016
	Acarospora leavittii K. Knudsen & Hollinger	2014 (as *Polysporina gyrocarpa* (H. Magn.) N. S. Golubk.), 2016
	Acarospora rosulata (Th. Fr.) H. Magn.	2014, 2016
	Acarospora socialis H. Magn.	2016
	Acarospora squamulosa (Schrad.) Trevis.	2014 (as *Acarospora peliscypha* Th. Fr.), 2016
	Acarospora stapfiana (Müll. Arg.) Hue	2014, 2016
	Acarospora strigata (Nyl.) Jatta	2014, 2016
Caliciaceae	*Buellia abstracta* (Nyl.) H.Olivier	2014, 2016
	Buellia dispersa A. Massal	2016
Candelariaceae	*Candelariella aurella* (Hoffm.) Zahlbr.	2016
	Candelariella citrina B. de Lesd.	2016
	Candelariella rosulans (Mull. Arg.) Zahlbr.	2014, 2016
Collemataceae	*Enchylium tenax* (Sw.) Gray	2014
Lecanoraceae	*Lecanora* cf. *utahensis* H. Magn.	2016
	Protoparmeliopsis garovaglii (Körb.) Arup, Zhao Xin & Lumbsch	2014 (as *Lecanora garovaglii* (Körber) Zahlbr.), 2016
	Protoparmeliopsis peltata (Lam. & DC.) Arup, Zhao Xin & Lumbsch	2016
	Rhizoplaca melanopthalma (DC.) Leuckert	2016
Lichinaceae	*Peccania subnigra* (B. de Lesd.) Wetmore	2016
Megasporaceae	cf. *Circinaria calcarea* (L.) A.Nordin, Savić & Tibell	2016
	Lobothallia alphoplaca (Wahlenb.) Hafellner	2016
Parmeliaceae	*Xanthoparmelia* cf. *maricopensis* T.H. Nash & Elix	2016
	Xanthoparmelia mexicana (Gyeln.) Hale	2016
Physciaceae	*Rinodina* cf. *athallina* H. Magn	2016
Psoraceae	*Psora tuckermanii* R.A. Anderson ex Timdal	2016
Teloschistaceae	*Gyalolechia desertorum* (Tomin) Søchting, Frödén & Arup	2016
	Rusavskia elegans (Link) S.Y. Kondr. & Kärnefelt	2016
	Xanthomendoza fallax (Arnold) Søchting, Kärnefelt & S.Y. Kondr.	2016
	Xanthomendoza trachyphylla (Tuck.) Frödén, Arup & Søchting	2014 (as *Caloplaca trachyphylla* (Tuck.) Zahlbr.), 2016
Verrucariaceae	*Clavascidium lacinulatum* (Ach.) Prieto	2016
	Dermatocarpon taminium Heiðm.	2016
	Heteroplacidium compactum (A. Massal.) Gueidan & Cl. Roux	2014, 2016
	Placidium acarosporoides (Zahlbr.) Breuss	2014, 2016
	Placidium lachneum (Ach.) B. de Lesd.	2014, 2016
	Staurothele areolata (Ach.) Lettau	2016
	Verrucaria bernardinensis Breuss	2016

Nunavut were also discarded with the following collection numbers: Srivastava DI1, DI14.

One specimen from Utah was only identified to genus (Murakami YM-22-01-02, *Peccania*) and two unidentified sterile crusts were retained for future identification (Murakami YM-38-02-01, YM-38-02-02). One of the collections was determined to be a moss when examined after the mission, this specimen (Murakami YM-13-01-02) was identified as *Pterogoneurum subsessile* (Brid.) Jur. by bryologist Jennifer Doubt at the Canadian Museum of Nature.

Ultimately, 102 specimens from Utah and 26 specimens from Nunavut were identified to species level. At MDRS we documented 35 lichen species from 12 families (Table 1); 13 of these species were documented at MDRS previously (Sokoloff et al. 2016). At FMARS we documented 13 species from 9 families (Table 2). These species are presented in the annotated checklists of collections from the Mars 160 mission below

Table 2. Lichen species collected at the Flashline Mars Arctic Research Station, (Nunavut, Canada) in 2017.

Family	Species
Candelariaceae	*Candelariella canadensis* H. Magn.
Lecanoraceae	*Lecanora marginata* (Schaer.) Hertel & Rambold
	Myriolecis dispersa (Pers.) Śliva, Zhao Xin & Lumbsch
Lecideaceae	*Farnoldia hypocrita* (A. Massal.) Fröberg
	Lecidella patavina (A. Massal.) Knoph & Leuckert
Megasporaceae	*Diplotomma* cf. *venustum* (Körb.) Körb.
Physciaceae	*Physconia muscigena* (Ach.) Poelt
Psoraceae	*Protoblastenia rupestris* (Scop.) J.Steiner
Rhizocarpaceae	*Rhizocarpon chioneum* (Norman) Th. Fr.
	Rhizocarpon geographicum (L.) DC.
Teloschistaceae	*Gyalolechia bracteata* (Hoffm.) A. Massal.
	Rusavskia elegans (Link) S.Y. Kondr. & Kärnefelt
Verrucariaceae	*Polyblastia hyperborea* Th. Fr.

(organized alphabetically by family and then by species).

Substrate ecology of lichens at MDRS and FMARS. At the eleven Utah collection sites that were geologically surveyed, the crew collected lichens and related their collections to the substrates and overall geomorphology of each site.

At "Shannon's Rock Garden" lichens were found on outcrops of the Brushy Basin Member of the Jurassic Morrison Formation. The species collected here: *Acarospora stapfiana* (Müll.Arg.) Hue*, A. strigata* (Nyl.) Jatta*, Buellia abstracta* (Nyl.) H. Olivier and *Xanthomendoza trachyphylla* (Tuck.) Frödén, Arup & Søchting, grew preferentially on upper and north-facing surfaces.

At "Hab Ridge", lichens were collected along Dakota sandstone exposures of the Cretaceous Dakota Sandstone along the ridgeline. The species collected here - *Acarospora strigata* and *Acarospora obpallens* (Nyl.) Zahlbr. - occur mostly on the upper surface, less so on south facing surfaces of the blocks. A tooth of a fossil lamelliform shark was found and higher in the stratigraphy are thick and widespread accumulations of the Cretaceous oyster *Pycnodonte* Fischer von Waldheim (1835).

Along the channel of the Brushy Basin member at "Galileo Road", *Candelariella rosulans* (Müll. Arg.) Zahlbr*, Heteroplacidium compactum* (A. Massal.) Gueidan & Cl. Roux, *Protoparmeliopsis garovaglii* (Körb.) Arup, Zhao Xin & Lumbsch*, Psora tuckermanii* R.A. Anderson ex Timdal, and *Xanthoparmelia mexicana* (Gyeln.) Hale occurred preferentially on the upper and north facing surfaces of the outcrops.

Clavascidium lacinulatum (Ach.) Prieto*, Dermatocarpon taminium* Heiðm.*, Protoparmeliopsis peltata* (Lam. & DC.) Arup, Zhao Xin & Lumbsch, and *Xanthoparmelia mexicana* were all found growing at the dry waterfall near the unnamed canyon between Tank Wash and the Junction of the 1572/1575.

At the cattle grid at the beginning of Cow Dung Road, where the gravels have been stable for some time (pedogenic carbonate has precipitated on the underside of some clasts), the upper surfaces of these gravels are colonized by *Acarospora strigata*. Samples AS24 and AS25 are on dacite (70% silica), AS26 and AS28 are on diorite (50-70% silica), and AS27 and AS29 are on basalt (50% silica). All are igneous rocks, diorites and basalts have low contents of sodium and potassium, while dacites have higher potassium contents.

The landscape above the box canyon in a quarry is capped by old terrace gravels. These are both colonized by lichens and have hypoliths beneath the quartz pebbles. Species here include *Acarospora rosulata* (Th. Fr.) H. Magn.*, A. strigata, Candelariella rosulans, Gyalolechia desertorum* (Tomin) Søchting, Frödén & Arup*, Lobothallia alphoplaca* (Wahlenb.) Hafellner*, Lecanora* cf. *utahensis* H. Magn.*, Rinodina* cf. *athallina* H. Magn., and *Verrucaria bernardinensis* Breuss.

Lichens collected at the site east of the Mars Desert Research Station include *Acarospora rosulata, A. stapfiana, Protoparmeliopsis peltata, Xanthoparmelia* cf. *maricopensis* T.H. Nash & Elix, and *Xanthomendoza trachyphylla*.

Lichens collected at "Cactus Road" include *Acarospora leavittii* K. Knudsen & Hollinger*, A. strigata, Acarospora squamulosa* (Schrad.) Trevis.*, Buellia dispersa* A. Massal*, Candelariella rosulans* and *Peccania subnigra* (B. de Lesd.) Wetmore.

At the "Valley of the Stars", lichens occur both on sandstone outcrops and on loose boulders that have rolled down the slope. Species collected include *Acarospora strigata, A. obpallens,* cf. *Circinaria calcarea* (L.) A.Nordin, Savić & Tibell*, Candelariella aurella* (Hoffm.) Zahlbr.*, Heteroplacidium compactum*, and *Staurothele areolata* (Ach.) Lettau.

At the "Ruined House" site, lichens were found on the southern and western aspect of boulders on the western side of the butte, and include: *Acarospora leavittii*, *A. rosulata*, *A.* cf. *squamulosa*, *Candelariella rosulans* and *Rhizoplaca melanophthalma* (DC.) Leuckert.

"Kissing Camel Ridge" is noted for a brilliant, yellow green lichen - *Acarospora socialis* H. Magn., which occurs on north facing boulders of conglomeratic sandstone. Most occurrences are close to the ground, no more than 40 cm above it, although a few are higher up (up to two meters). The occurrences are north-facing and almost over-hanging. Other lichen species at this site include *Dermatocarpon taminium* and *Placidium acarosporoides*.

Lichens collected at the four general locations and lithologies at the Flashline Mars Arctic Research Station in Nunavut are as follows.

In the vicinity of FMARS (July 20, 21, 26, 2017; Samples DI2 to DI15), lichens collected on the upper member of the Allen Bay Formation were: *Diplotomma* cf. *venustum* (Körb.) Körb., *Farnoldia hypocrita* (A. Massal.) Fröberg, *Lecanora marginata* (Schaer.) Hertel & Rambold, *Lecidella patavina* (A. Massal.) Knoph & Leuckert, *Myriolecis dispersa* (Pers.) Śliva, Zhao Xin & Lumbsch, *Polyblastia hyperborea* Th. Fr., *Protoblastenia rupestris* (Scop.) J.Steiner, *Rhizocarpon chioneum* (Norman) Th. Fr., *Rhizocarpon geographicum* (L.) DC., and *Rusavskia elegans* (Link) S.Y. Kondr. & Kärnefelt.

Species collected from the eastern rim of Haughton Impact Crater (July 29, 20178; Samples DI16 to DI24) include: *Diplotomma* cf. *venustum, Gyalolechia* cf. *bracteata* (Hoffm.) A. Massal, *Lecanora marginata,* cf. *Physconia muscigena* (Ach.) Poelt, and *Rusavskia elegans*.

Further east of the Haughton Impact crater, still along the crater rim, a specimen of *Rusavskia elegans* (July 30, 2018; Sample DI25) was collected on the Dolostone impact breccia.

In the northern half of the Haughton Impact Crater (August 1, 2017; Samples DI26 to DI27), *Candelariella canadensis* H. Magn. and *Gyalolechia bracteata* were collected.

Annotated checklist of new records from Utah

Acarosporaceae

Acarospora fuscata (Schrad.) Arnold

Figure 3A

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville**;** 38°24′44″N, 110°46′25″W; 02.XI.201602.XI.2016; Y. Murakami leg.; YM-22-01-03; CANL 10027284 • San Rafael Desert NW of Hanksville; 38°24′44″N, 110°46′25″W; 02.XI.2016; Y. Murakami leg.; YM-22-01-04; GenBank Accession Number: PP047688; CANL 10027320.

Identification. Thallus brown, crustose, rimose to areolate. Apothecia one per areole (sometimes more), small to covering entire areole, disc brown, epruinose. Asci multi-spored (100+ ascospores per ascus). Ascospores simple, ellipsoid, hyaline. Cortex KC+ red, C+ red (Nash et al. 2007).

Substrate. Saxicolous, on conglomerate.

Notes. This species was collected twice east of the station. It differs from other brown C+ red *Acarospora* species in the station area by its non-pitted, uniform (areolate to rimose) crust which is usually epruinose (not appearing frosted) (Nash et al. 2007). This species has also been collected on Bathurst Island, Nunavut (Consortium of Lichen Herbaria 2023). Identification was confirmed with the assistance of ITS DNA barcoding.

Acarospora leavittii K. Knudsen & Hollinger

Figure 3B

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville, "Cactus Road"; 38°24′35″N, 110°46′22″W; elev. 1,371 m; 02.XI.201602.XI.2016; A. Srivastava leg.; AS54; CANL 10027341 • San Rafael Desert NW of Hanksville, "Ruined House"; 38°24′16″N, 110°46′55″W; elev. 1,382 m; 18.XI.201618.XI.2016; A. Srivastava leg.; AS69; CANL 10027313 • San Rafael Desert NW of Hanksville; 38°24′45″N, 110°46′25″W; 02.XI.201602.XI.2016; Y. Murakami leg.; YM-22-02-01; CANL 10027269 • San Rafael Desert NW of Hanksville; 38°24′46″N, 110°46′28″W; 03.XI.2016; Y. Murakami leg.; YM-23-04-02; CANL 10027261).

Identification. Thallus apparently absent (endolithic in substrate). Apothecia dispersed on substrate, disc black, gyrose (with a margin twisted throughout the disc). Asci multi-spored (100+ ascospores per ascus). Ascospores simple, ellipsoid, hyaline. Spot tests negative (Nash et al. 2007).

Substrate. Saxicolous, on sandstone.

Notes. This species was previously reported for the station as *Polysporina gyrocarpa* (H. Magn.) N. S. Golubk., which is now *A. leavittii* (Knudsen et al. 2021). *Acarospora leavitti* also includes specimens from the area previously called *Polysporina cyclocarpa* (Anzi) Vězda per Knudsen and Kocourková (2009). It is the only *Acarospora* species from MDRS without an apparent thallus, and can be differentiated from other

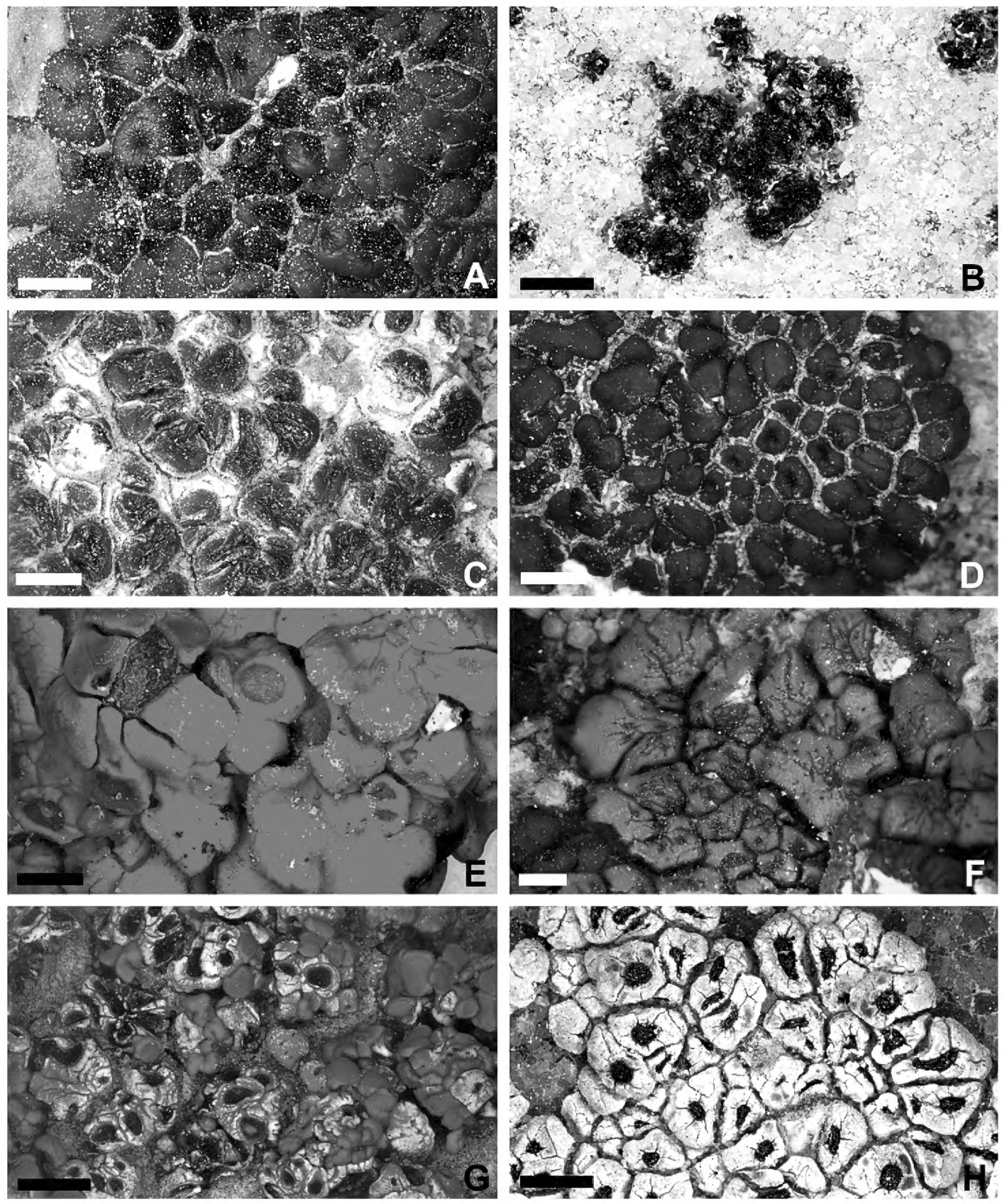

Figure 3. A. *Acarospora fuscata*, thallus and apothecia (Murakami YM-22-01-03). **B.** *Acarospora leavitii*, apothecia (Murakami YM-22-02-01). **C.** *Acarospora obpallens*, thallus and apothecia (Srivastava AS09). **D.** *Acarospora rosulata*, thallus and apothecia (Srivastava AS41). **E.** *Acarospora socialis*, apothecia (Srivastava AS77). **F.** *Acarospora squamulosa*, thallus and apothecia (Srivastava AS51). **G.** *Acarospora stapfiana*, thallus and apothecia (parasitic on orange *Xanthomendoza trachyphylla*) (associate of Srivastava AS02). **H.** *Acarospora strigata*, thallus and apothecia (Srivastava AS80). Scale bars: A–H = 1 mm.

endolithic species in the station area by its gyrose apothecia and polyspored asci with hyaline ascospores (Nash et al. 2007).

***Acarospora obpallens* (Nyl.) Zahlbr.**
Figure 3C

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville, "Hab Ridge"; 38°24′40″N, 110°47′44″W; elev. 1,410 m; 07.X.2016; A. Srivastava leg.; AS09; CANL 10027285 • San Rafael Desert NW of Hanksville, "Valley of the Stars"; 38°29′59″N, 110°55′32″W; elev. 1,480 m; 09.XI.2016; A. Srivastava leg.; AS67; CANL 10027283.

Identification. Thallus light to dark brown, crustose, areolate to verruculate. Apothecia one per areole (sometimes more), small to covering entire areole, disc brown, pruinose. Asci multi-spored (100+ ascospores per ascus). Ascospores simple, ellipsoid, hyaline. Cortex KC+ red, C+ red.

Substrate. Saxicolous, on sandstone.

Notes. Collected twice in the MDRS area (once near the station, and once in the "Valley of the Stars" gypsum deposit to the northwest), specimens from the station area appeared weathered. Compared to other brown, C+ red *Acarospora* species, *A. obpallens* often appears pitted and pruinose (Nash et al. 2007).

***Acarospora rosulata* (Th. Fr.) H. Magn.**
Figure 3D

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville, "Box Canyon Quarry"; 38°22′17″N, 110°45′04″W; elev. 1,370 m; 19.X.201619.X.2016; A. Srivastava leg.; AS30; CANL 10027306 • San Rafael Desert NW of Hanksville, east of Mars Desert Research Station; 38°24′13″N,

110°47′13″W; elev. 1,380 m; 29.X.201629.X.2016; A. Srivastava leg.; AS39; CANL 10027331 • same locality; 29.X.201629.X.2016; A. Srivastava leg.; AS41; CANL 10027248 • same locality; 29.X.201629.X.2016; A. Srivastava leg.; AS44; CANL 10027264 • San Rafael Desert NW of Hanksville, "Ruined House"; 38°24′16″N, 110°46′55″W; 1,380 m; 18.XI.201618.XI.2016; A. Srivastava leg.; AS71**;** CANL 10027247.

Identification. Thallus light brown, crustose, placodioid to areolate. Apothecia one or more per, usually not covering entire areole, disc brown, epruinose. Asci multi-spored (100+ spores per ascus). Ascospores simple, ellipsoid, hyaline. Cortex KC+ pinkish red, C+ red (Nash et al. 2007).

Substrate. Saxicolous, on sandstone.

Notes. Scattered in the station area, this species was treated in the Sonoran flora as *A. bullata* (Nash et al. 2007) which is now understood to be a primarily European taxon (Knudsen et al. 2010) and is only known in North America from Ontario, Canada (Brinker and Knudsen 2019). *Acarospora rosulata* differs from other brown, C+ red, *Acarospora* species in the station area by its primarily placodioid form.

***Acarospora socialis* H. Magn.**
Figure 3E

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville, "Kissing Camel Ridge East"; 38°23′34″N, 110°47′09″W; elev. 1,360 m; 23.XI.201623.XI.2016; A. Srivastava leg.; AS77; CANL 10027265.

Identification. Thallus yellow to greenish yellow, crustose, areolate to squamulose. Apothecia sometimes rare, one to many per areole, disc orange yellow, epruinose. Asci multi-spored (100+ spores per ascus). Ascospores simple, ellipsoid, hyaline. Spot tests negative. Thallus UV+ orange (Nash et al. 2007).

Substrate. Saxicolous, on sandstone and conglomerate.

Notes. This distinctive yellow species fluoresces orange under UV light; *A. stapfiana* is also UV+ orange but is greener, pruinose, and parasitic *on Xanthomendoza trachyphylla*. Recent work on the *A. socialis* aggregate has shown that many desert collections of this polymorphic species are *Acarospora radicata* (H. Magn.), which differs from the primarily pacific-coastal *A. socialis* in its desert habitat and up to 7 apothecia per areole (Knudsen and Kocourková 2021). The material from MDRS is too sparse with few apothecia, therefore pending revision of Utah material within this aggregate we are treating this specimen as *A. socialis* in the broad sense.

***Acarospora squamulosa* (Schrad.) Trevis.**
Figure 3F

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville, "Cactus Road"; 38°24′35″N, 110°46′22″W; elev. 1,370 m; 02.XI.201602.XI.2016; A. Srivastava leg.; AS51; CANL 10027294 • San Rafael Desert NW of Hanksville, "Ruined House"; 38°24′16″N, 110°46′55″W; elev. 1,380 m; 18.XI.201618.XI.2016; A. Srivastava leg.; AS73; CANL 10027286.

Identification. Thallus yellow-brown to brown, crustose, areolate to subsquamulose. Apothecia usually one, not filling areole, disc brown, epruinose. Asci multi-spored (100+ ascospores per ascus). Ascospores simple, ellipsoid, hyaline. Cortex KC+ pinkish red, C+ red (Nash et al. 2007).

Substrate. Saxicolous, on sandstone and conglomerate.

Notes. This species was previously collected at MDRS as *Acarospora peliscypha* Th. Fr. which is now a synonym of *A. squamulosa* (Knudsen et al. 2019). It might be mistaken for *A. rosulata*, but is generally subsquamulose, not placodioid (Nash et al. 2007). This species has also been reported from Axel Heiberg Island, Nunavut (Consortium of Lichen Herbaria 2023).

***Acarospora stapfiana* (Müll. Arg.) Hue**
Figure 3G

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville, "Shannon's Rock Garden"; 38°24′10″N, 110°47′13″W; elev. 1,370 m; 04.X.2016; A. Srivastava leg.; parasite on AS02; CANL 10027277.

Identification. Thallus pale yellow to yellowish green, crustose, squamulose. Apothecia one to many, one usually prominent and filling entire areole. Asci multi-spored (100+ ascospores per ascus). Ascospores simple, ellipsoid, hyaline. Spot tests negative. Thallus UV+ orange (Nash et al. 2007).

Substrate. Lichenicolous (parasitic) on *Xanthomendoza trachyphylla*, may become saxicolous in age.

Notes. This parasitic species is common on most instances of *Xanthomendoza trachyphylla* seen in the station area (Sokoloff, personal observation); mature specimens of the species may become independent of its host, in which case they can be differentiated from *A. socialis* by a pruinose thallus (Nash et al. 2007).

***Acarospora strigata* (Nyl.) Jatta**
Figure 3H

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville, "Shannon's Rock Garden"; 38°24′10″N, 110°47′13″W; elev. 1,370 m; 04.X.2016; A. Srivastava leg.; AS04; CANL 10027315 • San Rafael Desert NW of Hanksville, "Hab Ridge"; 38°24′40″N, 110°47′44″W; elev. 1,410 m; 07.X.2016; A. Srivastava leg.; AS05; CANL 10027340 • same locality; 07.X.2016; A. Srivastava leg.; AS06; CANL 10027317 • same locality; 07.X.2016; A. Srivastava leg.; AS08; CANL 10027288 • San Rafael Desert NW of Hanksville, cattle grid at start of Cow Dung Road; 38°22′12″N, 110°46′04″W; elev. 1,350 m; 17.X.2016; A. Srivastava leg.; • same locality; 17.X.2016; A. Srivastava leg.; AS24; CANL 10027318 • same locality; 17.X.2016; A. Srivastava leg.; AS25; CANL 10027246 • same locality; 17.X.2016; A. Srivastava leg.; AS26; CANL 10027274 • same locality; 17.X.2016; A. Srivastava leg.; AS27; CANL 10027280 • same locality; 17.X.2016; A. Srivastava leg.; AS28; CANL 10027333 • same locality; 17.X.2016; A. Srivastava leg.; AS29; CANL 10027305 • San Rafael Desert NW of Hanksville, "Box Canyon Quarry"; 38°22′17″N, 110°45′04″W; elev. 1,370 m; 19.X.201619.X.2016; A. Srivastava leg.; • same locality; 19.X.201619.X.2016; A. Srivastava leg.; AS31; CANL 10027282 • same locality; 19.X.2016; A. Srivastava leg.; AS32; CANL 10027301 • same locality; 19.X.2016; A. Srivastava leg.; AS36; CANL 10027281 • same locality; 19.X.2016; A. Srivastava leg.; AS37; CANL 10027287 • San Rafael Desert NW of Hanksville, "Cactus Road"; 38°24′35″N, 110°46′22″W; elev. 1,370 m; 02.XI.2016; A. Srivastava leg.; AS47; CANL 10027339 • same locality; 02.XI.2016; A. Srivastava leg.; AS48 CANL 10027293 • San Rafael Desert NW of Hanksville, "Valley of the Stars"; 38°29′59″N, 110°55′32″W; elev. 1,480 m; 09.XI.2016; A. Srivastava leg.; AS56; CANL 10027298 • same locality; 09.XI.2016; A. Srivastava leg.; AS57; CANL 10027289 • San Rafael Desert NW of Hanksville, "Valley of the Stars"; 38°29′59″N, 110°55′32″W; elev. 1,360 m; 09.XI.2016; A. Srivastava leg.; AS79; CANL 10027251 • San Rafael Desert NW of Hanksville, "Box Canyon Quarry"; 38°22′17″N, 110°45′04″W; elev. 1,370 m; 29.XI.2016; A. Srivastava leg.; AS80; CANL 10027335 • same locality; 29.XI.2016; A. Srivastava leg.; AS83; CANL 10027304 • same locality; 29.XI.2016; A. Srivastava leg.; AS84; CANL 10027321 • San Rafael Desert NW of Hanksville; 38°24′44″N, 110°46′25″W; 02.XI.2016; Y. Murakami leg.; YM-22-01-01; CANL 10027314 • San Rafael Desert NW of Hanksville; 38°24′44″N, 110°46′25″W; 03.XI.2016; Y. Murakami leg.; YM-23-01-01; CANL 10027243 • San Rafael Desert NW of Hanksville; 38°24′44″N, 110°46′29″W; 03.XI.2016; Y. Murakami leg.; YM-23-05-01; CANL 10027303. **Emery County** • San Rafael Desert NW of Hanksville; 38°30′04″N, 110°55′30″W; 09.XI.2016; Y. Murakami leg.; YM-27-02-01; CANL 10027338 • same locality; 09.XI.2016; Y. Murakami leg.; YM-27-02-02; CANL 10027271 • San Rafael Desert NW of Hanksville; 38°30′02″N, 110°55′39″W; 09.XI.2016; Y. Murakami leg.; YM-27-05-01; CANL 10027300 • same locality; 09.XI.2016; Y. Murakami leg.; YM-27-05-02; CANL 10027278.

Identification. Thallus bluish grey to grey, crustose, areolate to squamulose or verruculose. Apothecia one to several per areole, disc black to dark brown, pruinose or sometimes epruinose. Asci multi-spored (100+ ascospores per ascus). Ascospores simple, ellipsoid, hyaline. Spot tests negative (Nash et al. 2007).

Substrate. Saxicolous, on tacite, diorite, basalt, sandstone, gravelly sandstone conglomerate, and porphyritic diorite.

Notes. This whitish crustose species is extremely conspicuous and common in the MDRS area (Sokoloff et al. 2016) and was the most frequently collected species in 2016 (29 specimens), allowing for comprehensive observations of its local substrates (see above). This species can be differentiated from eroded specimens of *A. obpallens* by a C test (the cortex of *A. obpallens* is C+ red) (Knudsen and Lendemer 2005). Ongoing work on this widespread polymorphic species has uncovered cryptic diversity across the species' range (Leavitt et al. 2018; Nurtai et al. 2017) and may eventually require a reexamination of this taxon in the MDRS area.

Caliciaceae

***Buellia abstracta* (Nyl.) H. Olivier**
Figure 4A

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville, "Shannon's Rock Garden"; 38°24′10″N, 110°47′13″W; elev. 1,370 m; 04.X.2016; A. Srivastava leg.; AS03; CANL 10027332.

Identification. Thallus thin, crustose, to apparently absent (chasmolithic within substrate). Apothecia dispersed on substrate, discs black, without thalline rims, disc black. Asci 8-spored. Ascospores two-celled, brown, oblong to oblong-ellipsoid. Spot tests negative (Nash et al. 2007).

Substrate. Saxicolous on pebbly, conglomerated sandstone.

Notes. This species roughly corresponds with *Buellia sequax* in the Sonoran Flora (Nash et al. 2007, Giralt et al. 2011). This species is not likely to be confused with B. *dispersa*, which possesses a chalky white thallus; it can be differentiated from *Acarospora leavittii* by its brown, two-celled ascospores, and from *Rinodina athallina* by a brown epihymenium (vs. blue-gray in *R. athallina*) (Nash et al. 2007).

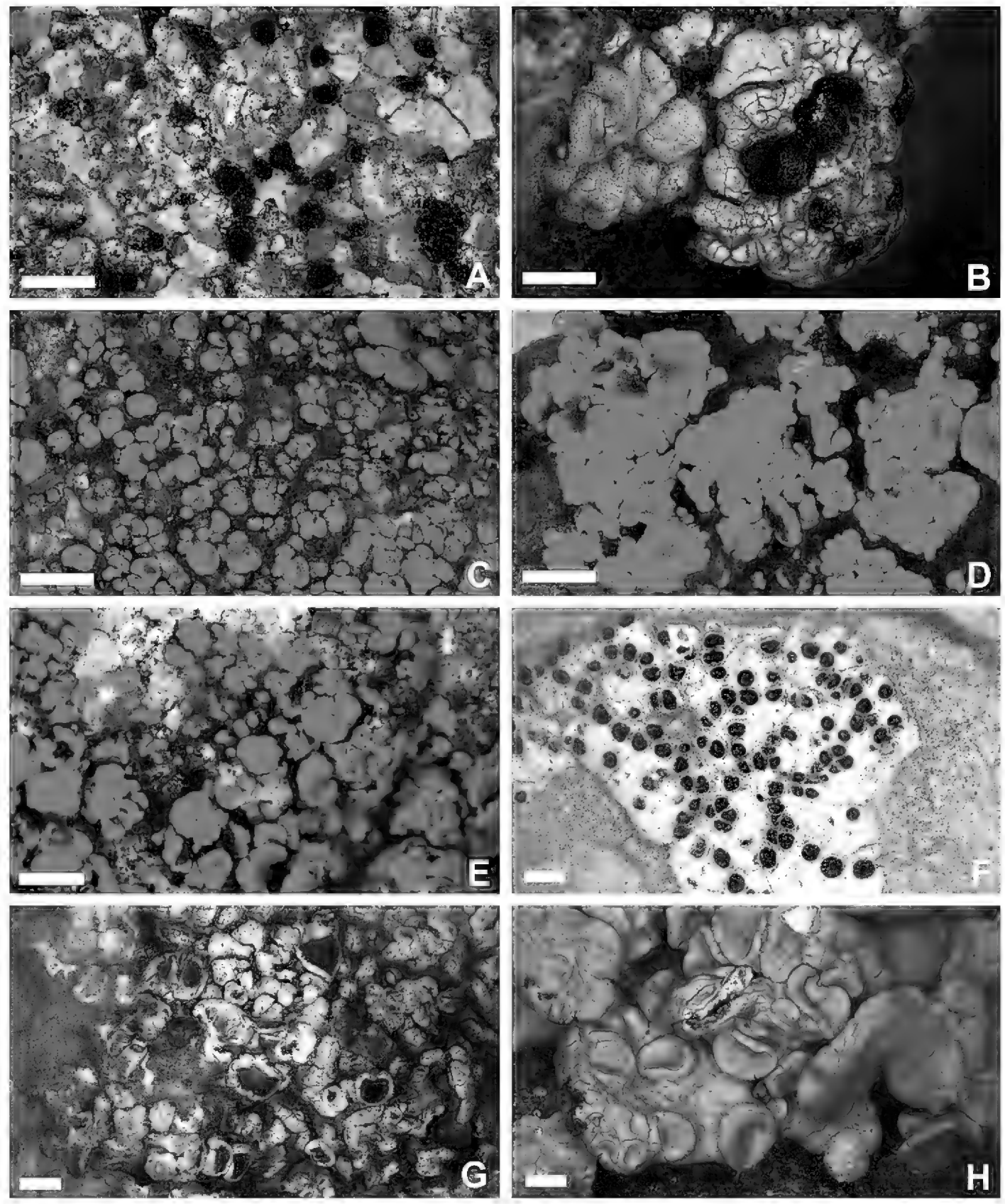

Figure 4. A. *Buellia abstracta*, apothecia (Srivastava AS03). **B.** *Buellia dispersa*, thallus and apothecia (Srivastava AS45). **C.** *Candelariella aurella*, thallus and apothecia (Srivastava AS60). **D.** *Candelariella citrina*, thallus and apothecia (Murakami YM-22-03-01). **E.** *Candelariella rosulans*, thallus and apothecia (Srivastava AS46). **F.** *Lecanora* cf. *utahensis*, weathered thallus and apothecia (Srivastava AS81). **G.** *Protoparmeliopsis garovaglii*, thallus and apothecia (Srivastava AS14). **H.** *Protoparmeliopsis peltata*, thallus and apothecia (Srivastava AS43). Scale bars: A–H = 1 mm.

***Buellia dispersa* A. Massal**
Figure 4B

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville, "Cactus Road"; 38°24′35″N, 110°46′22″W; elev. 1,370 m; 02.XI.2016; A. Srivastava leg.; AS45; CANL 10027330 • San Rafael Desert NW of Hanksville; 38°24′42″N, 110°46′28″W; 03.XI.2016; Y. Murakami leg.; YM-23-06-02; CANL 10027329.

Identification. Thallus white to grey, crustose, areolate. Apothecia black, dispersed on thallus, without thalline rims, disc black. Asci 8-spored. Ascospores two-celled, brown, oblong to oblong-ellipsoid. Thallus K+ yellow, P+ yellow (Nash et al. 2007).

Substrate. Saxicolous on sandstone.

Notes. Widely spread throughout the American southwest, morphological and genetic investigations of the group indicate that it likely contains additional undescribed species (Bungartz et al. 2002). This species can be differentiated from *B. abstracta* by its well developed, chalky white apothecia, and the absence of oil droplets in the hymenium (Nash et al. 2007).

Candelariaceae

***Candelariella aurella* (Hoffm.) Zahlbr.**
Figure 4C

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville, "Valley of the Stars"; 38°29′59″N, 110°55′32″W; elev. 1,480 m; 09.XI.2016; A. Srivastava leg.; AS60; CANL 10027255.

Identification. Thallus yellow, crustose, areolate to diffuse, and scattered. Apothecia yellow, dispersed on thallus, with thalline rims, disc yellow. Asci 8-spored. Ascospores simple (or two-celled), hyaline, ellipsoid. Thallus K– to K+ reddish (Nash et al. 2004).

Substrate. Saxicolous on sandstone.

Notes. This species is distinguished from the other *Candelariella* species at MDRS by its diffuse, sometimes apparently absent thallus with small, interspersed apothecia (Westberg 2007). This species has also been collected on Devon Island (Consortium of Lichen Herbaria 2023), so it may occur near FMARS as well.

***Candelariella citrina* B. de Lesd.**
Figure 4D

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville; 38°24′42″N, 110°46′30″W; 02.XI.2016; Y. Murakami leg.; YM-22-03-01; GenBank Accession Number: PP047690; CANL 10027262.

Identification. Thallus yellow, crustose, squamulose to areolate. Apothecia yellow, imperfectly round, dispersed on thallus, with thalline rims, disc yellow. Asci 8-spored. Ascospores simple (or two-celled), hyaline, ovoid to teardrop-shaped. Thallus K– to K+ reddish (Nash et al. 2004).

Substrate. Saxicolous on sandstone.

Notes. This species is morphologically similar to *C. rosulans*, but can be differentiated by pointed, ovoid to citriform ascospores (versus elongated and not pointed in *C. rosulans*) (Westberg 2007; Westberg et al. 2011). *Candelariella citrina* has also been reported from Devon Island (Consortium of Lichen Herbaria 2023), though this specimen has not been re-examined since work done clarifying the taxonomy of *C. citrina*, *Candelariella canadensis*, and *Candelariella terrigena* in the Canadian Arctic (Westberg 2010). Identification of this species was confirmed with the assistance of ITS DNA barcoding.

***Candelariella rosulans* (Müll. Arg.) Zahlbr.**
Figure 4E

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville, "Galileo Road"; 38°25′00″N, 110°46′19″W; elev. 1,400 m; 10.X.2016; A. Srivastava leg.; AS12; CANL 10027326 • San Rafael Desert NW of Hanksville, "Box Canyon Quarry"; 38°22′17″N, 110°45′04″W; elev. 1,370 m; 19.X.2016; A. Srivastava leg.; AS34; CANL 10027290 • San Rafael Desert NW of Hanksville,"Cactus Road"; 38°24′35″N, 110°46′22″W; elev. 1,370 m; 02.XI.2016; A. Srivastava leg.; AS46; CANL 10027334 • same locality; 02.XI.2016; A. Srivastava leg.; AS49; CANL 10027245 • same locality; 02.XI.2016; A. Srivastava leg.; AS53; CANL 10027319 • same locality; 02.XI.2016; A. Srivastava leg.; AS55; CANL 10027244 • San Rafael Desert NW of Hanksville,"Ruined House"; 38°24′16″N, 110°46′55″W; elev. 1,380 m; 18.XI.2016; A. Srivastava leg.; AS72 CANL 10027279 • San Rafael Desert NW of Hanksville; 38°24′40″N, 110°46′32″W; 02.XI.2016; Y. Murakami leg.; YM-22-04-01; CANL 10027263 • San Rafael Desert NW of Hanksville; 38°24′44″N, 110°46′29″W; 03.XI.2016; Y. Murakami leg.; YM-23-05-02; CANL 10027268.

Identification. Thallus yellow, crustose, bullate to lobulate or rosulate. Apothecia yellow, dispersed on thallus, with thalline rims, disc yellow. Asci 8-spored. Ascospores simple (or two-celled), hyaline, oblong to ellipsoid. Thallus K+ reddish (Nash et al. 2004).

Substrate. Saxicolous on sandstone.

Notes. A common species around MDRS and the deserts of the American Southwest (Nash et al. 2004), this species is similar to *C. citrina* but differs by its oblong ascospores without pointed ends (Westberg 2007; Westberg et al. 2011).

Lecanoraceae

***Lecanora* cf. *utahensis* H. Magn.**
Figure 4F

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville, "Box Canyon Quarry"; 38°22′17″N, 110°45′04″W; elev. 1,370 m; 29.XI.2016; A. Srivastava leg.; AS81; CANL 10027299.

Identification. Thallus white, crustose, chalky granulate to areolate. Apothecia dark brown to dark red to black, dispersed on thallus, with thalline rims, disc epruinose. Asci 8-spored. Ascospores simple, hyaline, ellipsoid. Spot tests negative (Nash et al. 2004).

Substrate. Saxicolous on sandstone.

Notes. This specimen fits well within the description of *Lecanora utahensis* (Nash et el. 2004), except for a degraded cortex (which may just be the result of erosion). Knudsen (2012) notes that the species may appear similar to *Acarospora strigata*, but can be differentiated by its large ascospores borne eight to an ascus. The type locality for this species, Ekker Ranch (Magnusson 1952), is approximately 40 km from MDRS.

***Protoparmeliopsis garovaglii* (Körb.) Arup, Zhao Xin & Lumbsch**
Figure 4G

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville, "Galileo Road"; 38°25′00″N, 110°46′19″W; elev. 1,400 m; 10.X.2016; A. Srivastava leg.; AS14; CANL 10027272 • same locality; 10.X.2016; A. Srivastava leg.; AS15; CANL 10027259.

Identification. Thallus pale yellowish green to grey, crustose, placodioid. Apothecia yellow, brown, greenish, or red, scattered but congested at centre of thallus, with thalline rims, disc usually epruinose. Asci 8-spored. Ascospores simple, hyaline, ellipsoid. Thallus K– to K+ yellow, cortex KC+ yellow (Nash et al. 2004).

Substrate. Saxicolous on sandstone and conglomerate.

Notes. Common and morphologically variable across the American Southwest (Nash et al. 2004) this species was previously recorded at MDRS as *Lecanora garovaglii* (Körb.) Zahlbr. (Sokoloff et al. 2016); new molecular evidence supported transfer of the species to *Protoparmeliopsis* (Zhao et al. 2016).

***Protoparmeliopsis peltata* (Lam. & DC.) Arup, Zhao Xin & Lumbsch**
Figure 4H

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville, between Tank Wash and junction of Bureau of Land Management Roads 1572/1575; 38°26′02″N, 110°47′43″W; 1,370 m; 15.X.2016; A. Srivastava leg.; AS21; CANL 10027327 • same locality; 15.X.2016; A. Srivastava leg.; AS22; CANL 10027327 • San Rafael Desert NW of Hanksville, east of Mars Desert Research Station; 38°24′13″N, 110°47′13″W; 1,380 m; 29.X.2016; A. Srivastava leg.; AS43; CANL 10027273.

Identification. Thallus greenish yellow to greyish yellow, foliose, lobed to umbilicate. Apothecia pinkish brown to reddish brown, common, with thalline rims, either immersed or exserted from the thallus; disc epruinose. Asci 8-spored. Ascospores simple, hyaline, ellipsoid to subglobose. Cortex KC+ yellow, medulla P+ orange (Nash et al. 2002).

Substrate. Saxicolous on sandstone.

Notes. Previously included in *Rhizoplaca*, but transferred to *Protoparmeliopsis* by Zhao et al. (2016), this species can be distinguished from other *Rhizoplaca* s.l. species in the station area by the presence of Pannarin (McCune, 1987) and the brown, epruinose, crater like apothecia (Nash et al. 2002).

***Rhizoplaca melanophthalma* (DC.) Leuckert**
Figure 5A

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville, "Ruined House"; 38°24′16″N, 110°46′55″W; elev. 1,380 m; 18.XI.2016; A. Srivastava leg.; AS70; CANL 10027310.

Identification. Thallus greenish yellow to greyish yellow, foliose, lobed to umbilicate. Apothecia greyish green to blackish, common, often congested and crowding out thallus, with lobed thalline rims, epruinose to pruinose. Asci 8-spored. Ascospores simple, hyaline, ellipsoid to subglobose. Cortex KC+ yellow, medulla P– to P+ yellow, C– to C+ red, KC– to KC+ red (Nash et al. 2002).

Substrate. Saxicolous on sandstone.

Notes. This species can be distinguished from other *Rhizoplaca* s.l. species at MDRS by the squamulose thallus and large blackish apothecia (Nash et al. 2002). Molecular work has found multiple cryptic species within *R. melanophthalma* (Leavitt et al. 2011; Leavitt et al. 2013). Pending a molecular assessment of our material we are treating this taxon in the broad sense. This species has also been collected on Devon Island, Nunavut (Consortium of Lichen Herbaria 2023).

Lichinaceae

***Peccania subnigra* (B. de Lesd.) Wetmore**
Figure 5B

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville, "Cactus Road"; 38°24′35″N, 110°46′22″W; elev. 1,370 m; 02.XI.2016; A. Srivastava leg.; AS52; CANL 10027295.

Identification. Thallus black, fruticose, forming cushions of round thalline protrusions. Apothecia black, scattered, with thalline margins. Asci 8-spored, biseriate. Ascospores simple, hyaline, broadly ellipsoid. Spot tests negative.

Substrate. Saxicolous on sandstone to terricolous on silt and sand.

Notes. One of two cyanolichens currently reported from MDRS (the other being *Enchylium tenax*), this soil-crust forming species has a distinctive thallus of finger-like protrusions that set it apart from other species in the area (Nash et al. 2007).

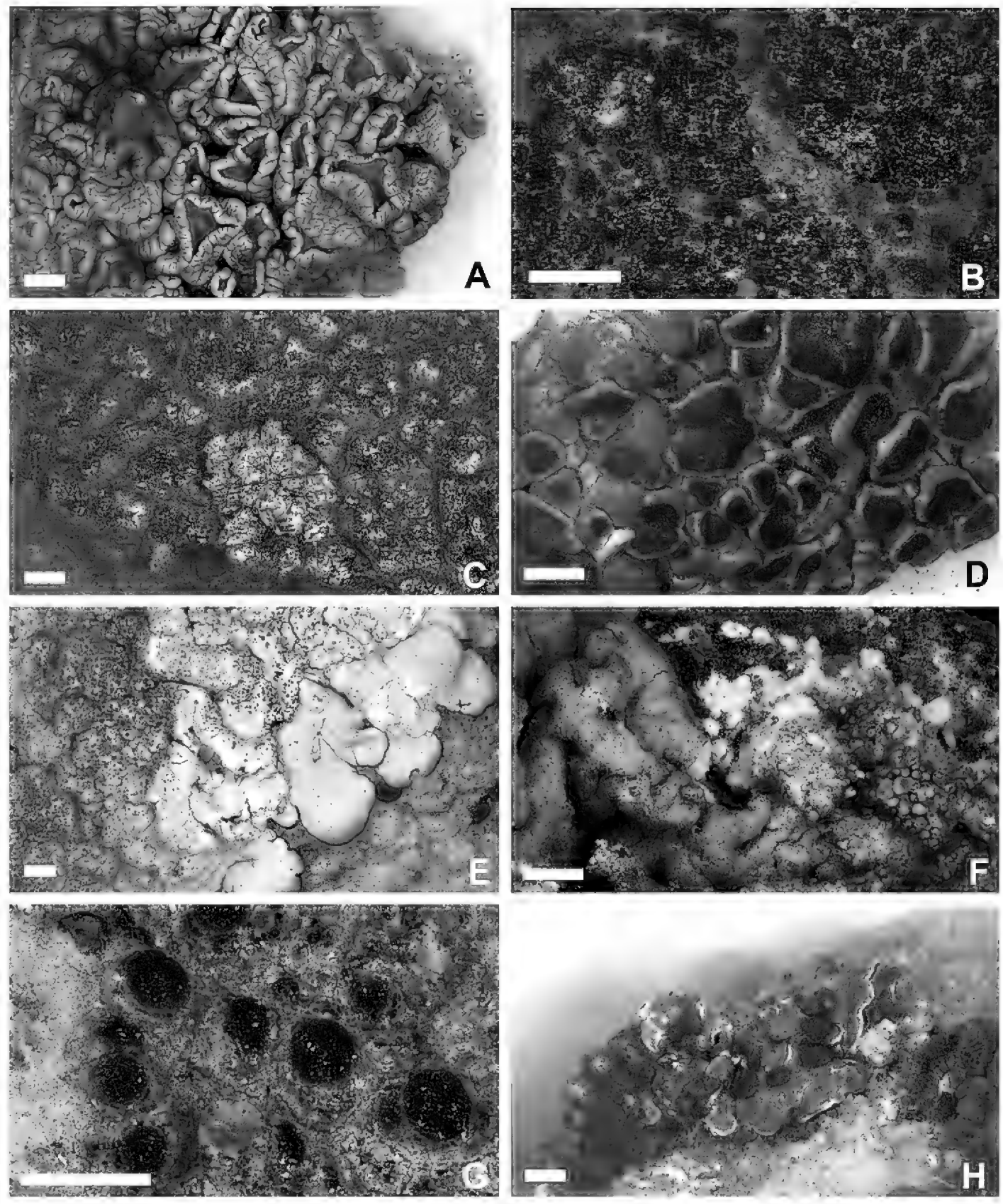

Figure 5. A. *Rhizoplaca melanophthalma*, apothecia and thallus (Srivastava AS70). **B.** *Peccania subnigra*, thallus (Srivastava AS52). **C.** cf. *Circinaria calcarea*, thallus (Srivastava AS58). **D.** *Lobothallia alphoplaca*, apothecia (Srivastava AS85). **E.** *Xanthoparmelia* cf. *maricopensis*, thallus and isidia (Srivastava AS40). **F.** *Xanthoparmelia mexicana*, thallus and isidia (Murakami YM-23-02-01). **G.** *Rinodina* cf. *athallina*, apothecia (Srivastava AS85). **H.** *Psora tuckermanii*, thallus and apothecia (Srivastava AS16). Scale bars: A–H = 1 mm.

Megasporaceae

cf. *Circinaria calcarea* (L.) A.Nordin, Savić & Tibell
Figure 5C

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville, "Valley of the Stars"; 38°29′59″N, 110°55′32″W; Elev. 1,480 m; 09.XI.2016; A. Srivastava leg.; AS58; GenBank Accession Number: PP047679; CANL 10027296.

Identification. Thallus white to grey, crustose, areolate, appearing cracked and fissured. Apothecia immersed in thallus, one or more per areole, disc grey to black, epruinose or pruinose. Asci 8-spored. Ascospores simple, hyaline, ellipsoid. Spot tests negative (Consortium of Lichen herbaria 2023).

Substrate. Saxicolous on sandstone.

Notes. DNA barcoding of this sterile specimen returned a high probability match for *Circinaria calcarea*, but we are retaining the cf. on this identification pending the collection of fertile material. This specimen may belong to *Circinaria arida* Owe-Larss., A.Nordin & Tibell pending revision of the American members of this genus (Owe-Larsson et al. 2011).

***Lobothallia alphoplaca* (Wahlenb.) Hafellner**
Figure 5D

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville, "Box Canyon Quarry"; 38°22′17″N, 110°45′04″W; elev. 1,370 m; 29.XI.2016; A. Srivastava leg.; AS85; GenBank Accession Number: PP047691; CANL 10027309.

Identification. Thallus blue-green to grey, greyish brown, or brown, crustose, areolate to placodioid.

Apothecia common, scattered, clustered towards centre of thallus, reddish brown to grey, with thalline margins, disc epruinose. Asci 8-spored. Ascospores simple, hyaline, shortly ellipsoid. Cortex K– to K+ red, P– to P+ orange, medulla K+ red, P+ orange (Nash et al. 2004).

Substrate. Saxicolous on basalt.

Notes. Collected once on volcanic basalt in the MDRS area, this species can superficially resemble *Acarospora*, but it has a thinner thalline margin (Sokoloff, personal observation). Common in the southwest United States, a useful key to the genus can be found in Paukov et al. (2019). This species has also been collected on Baffin Island, Nunavut (Consortium of Lichen Herbaria 2023). Identification of this species was confirmed with the assistance of ITS DNA barcoding.

Parmeliaceae

***Xanthoparmelia* cf. *maricopensis* T.H. Nash & Elix**
Figure 5E

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville, east of Mars Desert Research Station; 38°24′13″N, 110°47′13″W; elev. 1,380 m; 29.X.2016; A. Srivastava leg.; AS40; CANL 10027256.

Identification. Thallus yellow to yellowish green, foliose, lobate. Apothecia absent. Isidia common, clustered towards centre of thallus, globose to cylindrical, dull brown. Medulla K+ yellow to orange, P + orange (Nash et al. 2004).

Substrate. Saxicolous on basalt.

Notes. In the station area this species is distinguished by its globose, brown isidia, and the presence of norstictic acid, and is distinguished from its congener *Xanthoparmelia dierythra* (Hale) Hale by its smaller lobes (Nash et al. 2004).

***Xanthoparmelia mexicana* (Gyeln.) Hale**
Figure 5F

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville, "Galileo Road"; 38°25′00″N, 110°46′19″W; elev. 1,400 m; 10.X.2016; A. Srivastava leg.; AS13; CANL 10027266 • San Rafael Desert NW of Hanksville, between Tank Wash and junction of Bureau of Land Management Roads 1572/1575; 38°26′02″N, 110°47′43″W; elev. 1,370 m; 15.X.2016; A. Srivastava leg.; AS20; CANL 10027316 • San Rafael Desert NW of Hanksville; 38°24′45″N, 110°46′24″W; 03.XI.2016; Y. Murakami leg.; YM-23-02-01; CANL 10027323 • San Rafael Desert NW of Hanksville; 38°24′42″N, 110°46′28W; 03.XI.2016; Y. Murakami leg.; YM-23-7; CANL 10027275.

Identification. Thallus yellow to yellowish green, foliose, lobate. Apothecia uncommon, reddish brown, with thalline margins, disc epruinose. Asci 8-spored. Ascospores simple, hyaline, ellipsoid. Isidia common, clustered towards centre of thallus, globose to cylindrical, greenish brown to brown. Medulla K+ yellow to red, P + orange (Nash et al. 2004).

Substrate. Saxicolous on basalt.

Notes. More commonly encountered in the MDRS area than *X. maricopensis*, this species is distinguished by green isidia and the presence of salazinic acid (Nash et al. 2004). Molecular evidence indicates that the *X. mexicana* group needs taxonomic revision (Barcenas-Peña et al. 2018), therefore we treat the species here in the broad sense.

Physciaceae

***Rinodina* cf. *athallina* H. Magn.**
Figure 5G

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville, "Box Canyon Quarry"; 38°22′17″N, 110°45′04″W; elev. 1,370 m; 29.XI.2016; A. Srivastava leg.; AS82; GenBank Accession Number: PP047686; CANL 10027250.

Identification. Thallus pale grey to apparently absent (endolithic within substrate). Apothecia black, common, scattered on thallus, with black thalline margins, disc epruinose. Asci 8-spored. Ascospores two-celled, brown, narrowly ellipsoid and pointed at either end. Spot tests negative (Nash et al. 2004).

Substrate. Saxicolous on sandstone.

Notes. Like *Lecanora utahensis*, this species' type locality is also near MDRS at Ekker's Ranch (Magnusson 1952). *Rinodina athallina* may appear similar to the species of *Buellia* that grow near MDRS - including the two-celled, brown ascospores - but possess a distinct (even if thin) thalline margin distinct from the apothecial disc (Nash et al. 2004; Sheard, 2018). Identification of this species was confirmed with the assistance of

ITS DNA barcodes.

Psoraceae

***Psora tuckermanii* R.A. Anderson ex Timdal**
Figure 5H

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville, "Galileo Road"; 38°25′00″N, 110°46′19″W; elev. 1,400 m; 10.X.2016; A. Srivastava leg.; AS16; CANL 10027307.

Identification. Thallus grey brown to red brown, foliose, squamulose. Apothecia brown, common, along margins of squamules, globose, without thalline margins, epruinose or pruinose. Asci 8-spored. Ascospores simple, hyaline, broadly ellipsoid. Spot tests negative (Nash et al. 2002).

Substrate. Saxicolous on sandstone.

Notes. This species, common in the deserts of Utah (Timdal 1986), was encountered once in the MDRS area. It can be distinguished from other *Psora* species in the American southwest by its reddish-brown apothecia and pruinose thalline margins (McCune and Rosentreter 2007; Rosentreter et al. 2007).

Teloschistaceae

***Gyalolechia desertorum* (Tomin) Søchting, Frödén & Arup**
Figure 6A

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville, "Box Canyon Quarry"; 38°22′17″N, 110°45′48″W; elev. 1,370 m; 19.X.2016; A. Srivastava leg.; AS35; CANL 10027276.

Identification. Thallus whitish yellow to yellow or orange, crustose, often eroded. Apothecia common, scattered, yellow-orange to orange, with a thalline margin, disc epruinose or pruinose. Asci 8-spored. Ascospores two-celled, hyaline, ellipsoid. Spot tests negative (Nash et al. 2004).

Substrate. Terricolous on soil over conglomerate.

Notes. Encountered once in the MDRS area, this common desert species is distinctive due to its granular, lobate growth on soil (Nash et al. 2004). The lobate margins, along with one-septate ascospores, distinguish this species from *Gyalolechia bracteata* (Rosentreter et al. 2007). This species has also been collected on Axel Heiberg Island, Nunavut (Consortium of Lichen Herbaria 2023).

***Rusavskia elegans* (Link) S.Y. Kondr. & Kärnefelt**

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville; 38°24′06″N, 110°46′48″W; 19.XI.2016; Y. Murakami leg.; YM-38-03-01; CANL 10027336.

Identification. Thallus orange, foliose (appearing crustose), lobate. Apothecia common, clustered towards centre of thallus, orange, with thalline rims. Asci 8-spored. Ascospores polarilocular (two-celled with a perforated septum), hyaline, ellipsoid. Thallus K+ purple (Nash et al. 2004).

Substrate. Saxicolous on sandstone.

Notes. In the MDRS area this species is differentiated from the much more common *Xanthomendoza trachyphylla* by the presence of a lower cortex (Nash et al. 2004). For additional notes, see this species entry below for Nunavut.

***Xanthomendoza fallax* (Arnold) Søchting, Kärnefelt & S.Y. Kondr.**
Figure 6B

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville; 38°24′38″N, 110°46′28″W; 02.XI.2016; Y. Murakami leg.; YM-22-05-01; CANL 10027249.

Identification. Thallus orange, foliose (appearing crustose), lobate. Apothecia rare, on margins. Asci 8-spored. Ascospores polarilocular (two-celled with a perforated septum), hyaline, ellipsoid. Soredia common, in marginal fold of thallus. Thallus K+ purple (Nash et al. 2004).

Substrate. Lignicolous on old wood.

Notes. The only lignicolous (growing on wood) species collected at MDRS in 2016, this widespread species (Consortium of Lichen Herbaria 2023) has several congeners that may occur in the area – a useful key is provided in Lindblom (2006). This species has also been reported from Capitol Reef National Park (Yearsley et al. 1998) and on mainland Nunavut (Consortium of Lichen Herbaria 2023).

***Xanthomendoza trachyphylla* (Tuck.) Frödén, Arup & Søchting**

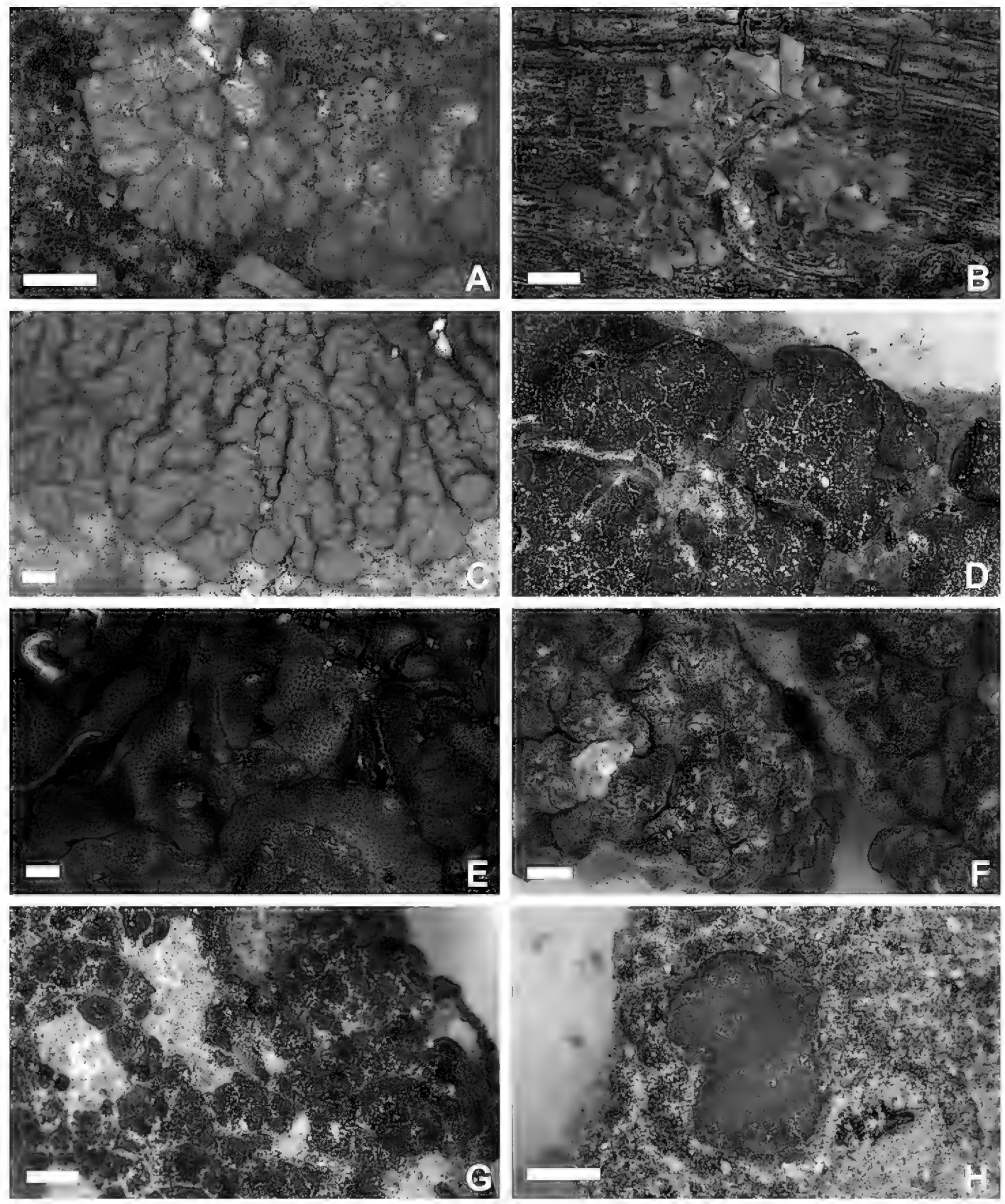

Figure 6. A. *Gyalolechia desertorum*, thallus (Srivastava AS35). **B.** *Xanthomendoza fallax*, thallus and soralia (Murakami YM-22-05-01). **C.** *Xanthomendoza trachyphylla*, thallus and apothecia (Murakami YM-13-02-01). **D.** *Clavascidium lacinulatum*, thallus (Srivastava AS19). **E.** *Dermatocarpon taminium*, thallus (Srivastava AS75). **F.** *Heteroplacidium compactum*, thallus (Srivastava AS18). **G.** *Placidium acarosporoides*, thallus (Murakami YM-13-01-01). **H.** *Placidium lachneum*, thallus (Murakami YM-23-04-01). Scale bars: A–H = 1 mm.

Figure 6C

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville, "Shannon's Rock Garden"; 38°24′10″N, 110°47′13″W; elev. 1,370 m; 04.X.2016; A. Srivastava leg.; AS02; CANL 10027277 • San Rafael Desert NW of Hanksville, east of Mars Desert Research Station; 38°24′13″N, 110°47′13″W; elev. 1,380 m; 29.X.2016; A. Srivastava leg.; AS42; CANL 10027328 • San Rafael Desert NW of Hanksville; 38°25′28″N, 110°47′20″W; 18.X.2016; Y. Murakami leg.; YM-13-02-01; CANL 10027257 • same locality; 19.X.2016; Y. Murakami leg.; YM-13-02-02; CANL 10027254 • San Rafael Desert NW of Hanksville; 38°24′42″N, 110°46′28″W;03.XI.2016; Y. Murakami leg.; YM-23-06-01; CANL 10027270 • San Rafael Desert NW of Hanksville; 38°24′06″N, 110°46′48″W; 19.XI.2016; Y. Murakami leg.; YM-38-03-02; CANL 10027337.

Identification. Thallus light to dark orange, crustose, lobate. Apothecia common, scattered near centre of thallus, with thalline margins, disc orange, epruinose. Asci 8-spored. Ascospores polarilocular (two-celled with a perforated septum), hyaline, ellipsoid. Thallus K+ red (Nash et al. 2004).

Substrate. Saxicolous on sandstone.

Notes. This bright orange species forms conspicuous large colonies on protected sandstone surfaces throughout the MDRS area (Sokoloff et al. 2016). It can be differentiated from *Rusavskia elegans* by its absent lower cortex (Nash et al. 2004). Mature colonies are frequently host to *Acarospora stapfiana* (Sokoloff, personal observation). While the core range of this species distribution is the southwest United States, disjunct populations are known from Svalbard in the European Arctic (Elvebakk and Øvstedal 2009).

Verrucariaceae

***Clavascidium lacinulatum* (Ach.) Prieto**
Figure 6D

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville, between Tank Wash and junction of Bureau of Land Management Roads 1572/1575; 38°26′02″N, 110°47′43″W; elev. 1,370 m; 15.X.2016; A. Srivastava leg.; AS19; GenBank Accession Number: PP047677; CANL 10027292.

Identification. Thallus brown to brownish black, squamulose. Perithecia along margins of thalli, subglobose or pyriform, colourless to brown. Asci 8-spored. Ascospores simple, hyaline, ellipsoid. Spot tests negative (Nash et al. 2002).

Substrate. Terricolous on silt and sand.

Notes. Rhizines present on the underside of the thallus are an important character separating it from *Catapyrenium squamulosum* (Ach.) Breuss (Nash et al. 2002), which is not yet reported from the study area and lacks rhizines. Previously placed within *Placidium*, molecular work supported a transfer to *Clavascidium* (Prieto et al. 2012). This species has also been reported on mainland Nunavut (Consortium of Lichen Herbaria 2023). Identification of this species was confirmed with the assistance of ITS DNA barcoding.

***Dermatocarpon taminium* Heiðm.**
Figure 6E

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville, between Tank Wash and junction of Bureau of Land Management Roads 1572/1575; 38°26′02″N, 110°47′43″W; elev. 1,370 m; 15.X.2016; A. Srivastava leg.; AS22; CANL 10027242 • San Rafael Desert NW of Hanksville, "Kissing Camel Ridge East"; 38°23′34″N, 110°47′09″W; elev. 1,360 m; 23.XI.2016; A. Srivastava leg.; AS75; CANL 10027308.

Identification. Thallus grey to black, foliose, lobate to umbilicate. Perithecia pyriform to globose, scattered on thallus. Asci 8-spored. Ascospores simple, hyaline, ellipsoid. Spot tests negative (Nash et al. 2004).

Substrate. Saxicolous on sandstone.

Notes. With its black foliose thallus, this species is distinctive in the MDRS area. It is distinguished from the closely related *Dermatocarpon miniatum* (L.) W. Mann by its long ascospores (Heiðmarsson, 2003). While this species is common in parts of Nevada (Carter et al. 2019; St. Clair et al. 2021), Arizona and California (Knudsen et al. 2017) and other surrounding states (Consortium of Lichen Herbaria 2023), this appears to be only the second published record of this species for Utah (after Munger et al. 2022).

***Heteroplacidium compactum* (A. Massal.) Gueidan & Cl. Roux**
Figure 6F

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville, "Galileo Road", 38°25′00″N, 110°46′19″W; elev. 1,400 m; 10.X.2016; A. Srivastava leg.; AS18; CANL 10027267 • San Rafael Desert NW of Hanksville, "Valley of the Stars"; 38°29′59″N, 110°55′32″W; elev. 1,480 m; 09.XI.2016; A. Srivastava leg.; AS68; CANL 10027258 • San Rafael Desert NW of Hanksville; 38°24′46″N, 110°46′27″W;03. XI.2016; Y. Murakami leg.; YM-23-03-01; CANL 10027302.

Identification. Thallus dark brown, crustose, areolate to squamulose. Perithecia common, immersed in thallus, subglobose. Asci 8-spored. Ascospores simple, ellipsoid. Spot tests negative (Nash et al. 2007).

Substrate. Saxicolous on sandstone and terricolous on sand or silt.

Notes. Sometimes lichenicolous on *Staurothele* and other lichen species, including possibly *Xanthomendoza trachyphylla* (Sokoloff et al. 2016). The bullate dark brown thallus sets it apart from similar species in the MDRS area (Nash et al. 2007).

***Placidium acarosporoides* (Zahlbr.) Breuss**
Figure 6G

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville, "Box Canyon Quarry"; 38°22′17″N, 110°45′04″W; elev. 1,370 m; 19.X.2016; A. Srivastava leg.; AS33b; GenBank Accession Number: PP047684; CANL 10027357 • San Rafael Desert NW of Hanksville, "Kissing Camel Ridge East"; 38°23′34″N, 110°47′09″W; elev. 1,360 m; 23.XI.2016; A. Srivastava leg.; AS76; GenBank Accession Number: PP047687; CANL 10027252 • San Rafael Desert NW of Hanksville; 38°25′27″N, 110°47′19″W; 18.X.2016; Y. Murakami leg.; YM-13-01-01; CANL 10027260.

Identification. Thallus dark brown, red brown, to black, crustose, areolate to bullate. Perithecia common, subglobose, partially immersed. Asci 8-spored. Ascospores simple, hyaline, broadly ellipsoid. Spot tests negative (Nash et al. 2002).

Substrate. Saxicolous on sandstone.

Notes. This species can be distinguished from *P. lachneum* by its subglobose perithecia, and glossy, slightly convex squamules, and a lower cortex without angular cells (Nash et al. 2002). Identification of this species was confirmed with the assistance of ITS DNA barcodes.

***Placidium lachneum* (Ach.) B. de Lesd.**
Figure 6H

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville; 38°24′46″N, 110°46′28″W;03.XI.2016; Y. Murakami leg.; YM-23-04-01; CANL 10027291.

Identification. Thallus red brown to dark brown, squamulose. Perithecia along margins of thalli, broadly pyriform, colourless. Asci 8-spored. Ascospores simple, hyaline, broadly ellipsoid. Spot tests negative (Nash et al. 2002).

Substrate. Saxicolous on sandstone.

Notes. The angular, stacked cells of this species' lower cortex set it apart from all other *Placidium* species in the American southwest (Nash et al. 2002). Previously reported at MDRS (Sokoloff et al. 2016 – where these cells are illustrated), this common desert species is also known from Baffin Island and mainland Nunavut (Thomson 1997).

***Staurothele areolata* (Ach.) Lettau**
Figure 7A

Material examined. USA – UTAH/WAYNE COUNTY • San Rafael Desert NW of Hanksville, "Valley of the Stars"; 38°29′59″N, 110°55′32″W; elev. 1,480 m; 09.XI.2016; A. Srivastava leg.; AS65; CANL 10027311 • same locality; 09.XI.2016; A. Srivastava leg.; AS66; CANL 10027322.

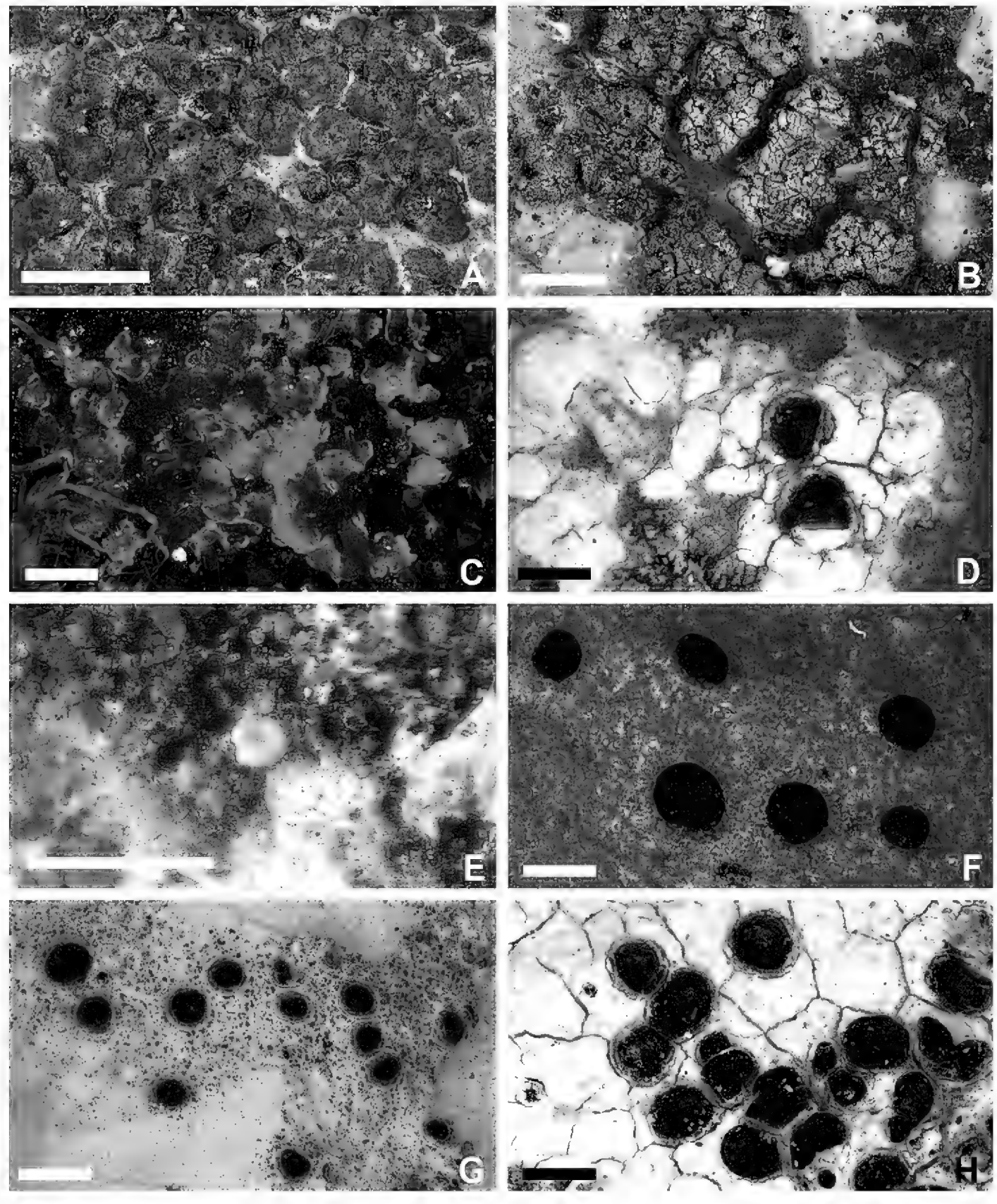

Figure 7. A. *Staurothele areolata*, thallus and perithecia (Srivastava AS65). **B.** *Verrucaria bernardinensis*, thallus (parasitic on *Placidium acarosporoides*) (Srivastava AS33). **C.** *Candelariella canadensis*, thallus and apothecia (Srivastava DI26). **D.** Lecanora marginata, thallus and apothecia (Srivastava DI24). **E.** *Myriolecis dispersa*, thallus (Srivastava DI18). **F.** *Farnoldia hypocrita*, apothecia (Srivastava DI2). **G.** *Lecidella patavina*, thallus and apothecia (Srivastava DI9b). **H.** *Diplotomma* cf. *venustum*, thallus and apothecia (Srivastava DI21). Scale bars: A–H = 1 mm.

Identification. Thallus light brown to dark brown, crustose, areolate to subsquamulose. Perithecia uncommon, on larger areoles, dark brown and confluent with thallus. Asci 2-spored. Ascospores ellipsoid, dark brown, muriform. Spot tests negative (Nash et al. 2002).

Substrate. Saxicolous on sandstone.

Notes. The muriform, dark brown ascospores of this species help differentiate it from other Verrucariaceae species in the MDRS area. Common in the American southwest, this species is also known from Bathurst and Axel Heiberg islands in Nunavut (Thomson 1997)

***Verrucaria bernardinensis* Breuss**
Figure 7B

Material examined. USA – Utah/Wayne County • San Rafael Desert NW of Hanksville, "Box Canyon Quarry"; 38°22′17″N, 110°45′04″W; elev. 1,370 m; 19.X.2016; A. Srivastava leg.; AS33; GenBank Accession Number: PP047685; CANL 10027312.

Identification. Thallus grey to grey brown, areolate. Perithecia common, immersed within thallus. Asci 8-spored. Ascospores simple, hyaline, subglobose. Spot tests negative (Nash et al. 2007).

Substrate. Lichenicolous in *Placidium*, *Staurothele*.

Notes. This greyish lichen often starts its life cycle as a parasite on *Staurothele*, before becoming independent (Kocourková et al. 2012). A taxonomically challenging group, subglobose ascospores in mature perithecia are important for accurate identification (Nash et al. 2007). Identification of this species was confirmed with the assistance of ITS DNA barcoding.

Annotated checklist of new records from Nunavut

Candelariaceae

***Candelariella canadensis* H. Magn.**
Figure 7C

Material examined. CANADA – Nunavut/Qikiqtaaluk Region • Devon Island, Haughton Crater; 75°24′52″N, 089°37′58″W; 01.VIII.2017; A. Srivastava leg.; DI26; CANL 10027351.

Identification. Thallus yellow, crustose, granular to areaolate, dispersed on substrate. Apothecia common, scattered, with a thalline rim, disc yellow, epruinose. Asci 8-spred. Ascospores simple, hyaline, ellipsoid. Spot tests negative (Consortium of Lichen Herbaria 2023)

Substrate. Terricolous/bryicolous.

Notes. *Candelariella terrigena* was reported from northeastern Devon Island by Barrett and Thomson (1975), which may include this species as Thomson (1997) included *C. canadensis* in his concept of *C. terrigena*. More recent work has synonymized *C. terrigena* under *C. citrina*, however, our material fits *C. canadensis* in habitat and morphology (Westberg 2010; Westberg 2011).

Lecanoraceae

***Lecanora marginata* (Schaer.) Hertel & Rambold**
Figure 7D

Material examined. CANADA – Nunavut/Qikiqtaaluk Region • Devon Island, Haughton Crater; 75°26′20″N, 089°48′07″W; 26.VII.2017; A. Srivastava leg.; DI5; CANL 10027344 • Devon Island, Haughton Crater; 75°24′48″N, 089°48′56″W; 29.VII.2017; A. Srivastava leg.; DI16; CANL 10027365 • Devon Island, Haughton Crater; 75°24′44″N, 089°48′45″W; 29.VII.2017; A. Srivastava leg.; DI22; CANL 10027367 • Devon Island, Haughton Crater; 75°24′46″N, 089°48′39″W; 29.VII.2017; A. Srivastava leg.; DI24; CANL 10027345.

Identification. Thallus white to grey white, crustose, chalky over a white prothallus. Apothecia common, scattered on thallus, with a black thalline rim, disc black, epruinose. Asci 8-spored. Ascospores simple, hyaline, ellipsoid. Cortex K+ yellow, KC+ yellow, medulla K– or K+ yellow, P– or P+ yellow (Nash et al. 2004).

Substrate. Saxicolous on limestone.

Notes. This species is common on the limestone shale of neighboring Cornwallis and Ellesmere islands (Thomson 1997); on Devon there is a collection recorded from Viks Fiord (Consortium of Lichen Herbaria 2023) northwest of FMARS. This species can superficially resemble *Rhizocarpon chioneum* but can be differentiated by *R. chioneum*'s one-septate ascospores and a red hypothecium (Nash et al. 2004). This species has also been collected in alpine areas in Utah (Consortium of Lichen Herbaria 2023).

***Myriolecis dispersa* (Pers.) Śliva, Zhao Xin & Lumbsch**
Figure 7E

Material examined. CANADA – Nunavut/Qikiqtaaluk Region • Devon Island, Haughton Crater; 75°26′11″N, 089°49′06″W; 26.VII.2017; A. Srivastava leg.; DI8; CANL 10027361.

Identification. Thallus apparently absent (endolithic within substrate), crustose. Apothecia common, scattered on substrate, disc pale to dark brown with a pale thalline rim, epruinose to pruinose. Asci 8-spored. Ascospores simple, hyaline, ellipsoid. Thalline rim of apothecia P– to P+ orange, UV– to UV+ yellow/green (Nash et al. 2004).

Substrate. Saxicolous on limestone.

Notes. Previously recorded at Truelove Lowlands on northeast Devon Island (Barrett and Thomson 1975) as *Lecanora dispersa* (Pers.) Somm, this taxon has been since transferred to *Myriolecis* (Zhao et al. 2016). This species has been collected from scattered locations in the Canadian Arctic Archipelago, as well as sites in Utah (Consortium of Lichen Herbaria 2023).

Lecideaceae

***Farnoldia hypocrita* (A. Massal.) Fröberg**
Figure 7F

Material examined. CANADA – Nunavut/Qikiqtaaluk Region • Devon Island, Haughton Crater; 75°25′49″N, 089°49′49″W; 21.VII.2017; A. Srivastava leg.; DI2; CANL 10027347.

Identification. Thallus apparently absent (endolithic within substrate) or slightly white, crustose. Apothecia common, scattered on substrate, disc black without a thalline rim. Asci 8-spored. Ascospores simple, ellipsoid with pointed ends, halonate. Medulla I+ blue, exciple and hypothecium K+ red-violet in section (Thompson 1997). This species has also been collected in Dixie National Forest, Utah (Consortium of Lichen Herbaria 2023).

Substrate. Saxicolous on limestone.

Notes. This species is only so far known in the Canadian Arctic Archipelago from limestone rich areas on Devon, Cornwallis, and Baffin Islands (Thomson 1997). While not reported from the Truelove Lowlands on northeast Devon Island by Barrett and Thomson (1975), five undated specimens of this species from the site collected by R.B. Schulten at the site are deposited at the University of Wisconsin - Madison (WIS) (Consortium of Lichen Herbaria 2023).

***Lecidella patavina* (A. Massal.) Knoph & Leuckert**
Figure 7G

Material examined. CANADA – Nunavut/Qikiqtaaluk Region • Devon Island, Haughton Crater; 75°26′19″N, 089°48′45″W; 26.VII.2017; A. Srivastava leg.; DI9; CANL 10027359.

Identification. Thallus pale white, yellowish, to apparently absent (endolithic within substrate), crustose. Apothecia common, scattered on thallus, with a black thalline rim, disc black, epruinose. Asci 8-spored. Ascospores simple, hyaline, ellipsoid to ovoid. Thallus K– to K+ yellow, C– to C+ yellow/red, P– to P+ yellow (Nash et al. 2004).

Substrate. Saxicolous on limestone.

Notes. Previously collected from the Truelove Lowlands (Barrett and Thomson 1975), this species keys out to *Lecidella inamoena* (Müll. Arg.) Hertel in Thomson (1997), now considered a synonym of *L. patavina* (Esslinger 2021). This species possesses a blue-green epihymenium, which is characteristic of *Lecidella*, and can be used when differentiating morphologically similar genera at FMARS. It has also been collected from Capitol Reef National Park, Utah (Consortium of Lichen Herbaria 2023).

Megasporaceae

***Diplotomma* cf. *venustum* (Körb.) Körb.**
Figure 7H

Material examined. CANADA – Nunavut/Qikiqtaaluk Region • Devon Island, Haughton Crater; 75°25′45″N, 089°48′44″W; 20.VII.2017; A. Srivastava leg.; DI11; CANL 10027348 • Devon Island, Haughton Crater; 75°24′45″N, 089°48′43″W; 29.VII.2017; A. Srivastava leg.; DI21; GenBank Accession Number: PP047681; CANL 10027353.

Identification. Thallus white to white grey, crustose, rimose. Apothecia common, scattered on thallus or clustered near centre, with a black thalline margin, disc black, pruinose. Asci 8-spored. Ascospores four-celled, sometimes two or three-celled, brown, ellipsoid and slightly curved (Nash et al. 2007).

Substrate. Saxicolous on limestone.

Notes. While *Diplotomma* species in the Canadian Arctic need revision (Thomson, 1997, where they are treated under *Buellia*), these specimen fits *D. venustum* morphologically (Nordin 2000; Nash et al. 2007) and via DNA barcoding (of DI21). This specimen is also clearly saxicolous and not parasitic, which fits only *Diplotomma alboatrum* and *D. venustum* – the former of which has muriform spores and is less common in eastern North America (Lendemer 2009). We retain the cf. on this identification pending revision of the group and due to the variation in ascospore cell number. *Diplotomma vensutum* has been confirmed on Victoria Island in the Canadian Arctic Archipelago (Consortium of Lichen Herbaria 2023). It has also been collected from Wayne County and Capitol Reef National Park, Utah (Consortium of Lichen Herbaria 2023). Identification of this species was confirmed with the assistance of an ITS DNA barcoding.

Physciaceae

***Physconia muscigena* (Ach.) Poelt**
Figure 8A

Material examined. CANADA – Nunavut/Qikiqtaaluk Region • Devon Island, Haughton Crater; 75°24′ 46″N, 089°48′39″W; 29.VII.2017; A. Srivastava leg.; DI19; CANL 10027362.

Identification. Thallus grey to brown, pruinose, foliose, lobed. Apothecia common but specimens often seen without them, when present with thalline rims, disc brown, epruinose. Asci 8-spored. Ascospores two-celled, brown. Spot tests normally negative, sometimes K+ yellow, KC+ yellow/orange (Nash et al. 2002).

Substrate. Bryicolous.

Notes. The only foliose species collected at FMARS in 2017, this species was previously reported for Devon Island (Barrett and Thomson, 1975), and on neighbouring Cornwallis Island, where Sowter (1960) reported

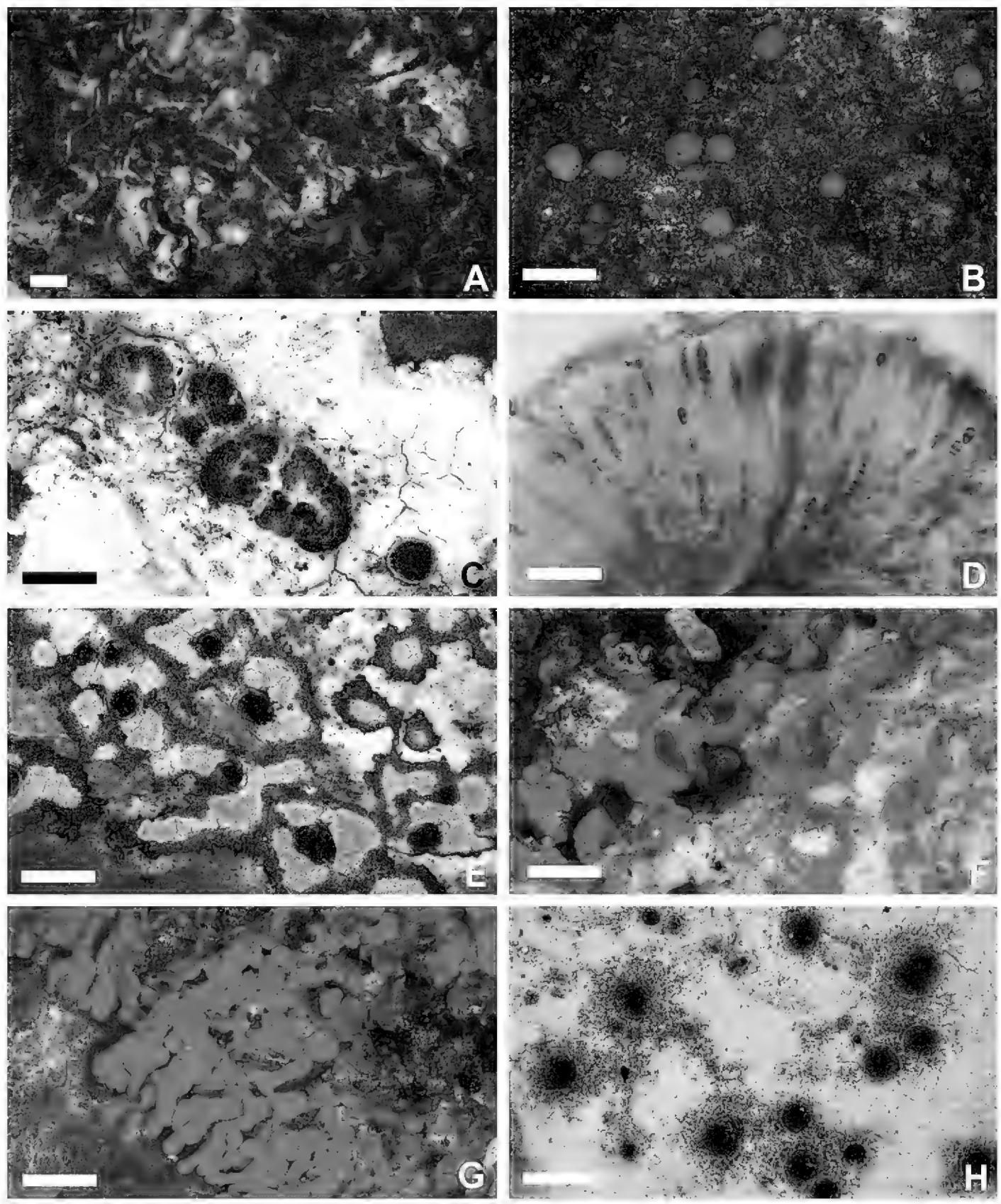

Figure 8. A. *Physconia muscigena*, thallus (Srivastava DI19). **B.** *Protoblastenia rupestris*, apothecia (Srivastava DI7). **C, D.** *Diplotomma* cf. *venustum*, thallus and apothecia (**C**), apothecial section with red hypothecium and one-septate spores (**D**) (Srivastava DI26). **E.** *Rhizocarpon geographicum*, thallus and apothecia (Srivastava DI23). **F.** *Gyalolechia bracteata*, thallus and apothecia (Srivastava DI27). **G.** *Rusavskia elegans*, thallus and apothecia (Srivastava DI25). **H.** *Polyblastia hyperborea*, perithecia (Srivastava DI9a). Scale bars: A–C, E–H = 1 mm. D = 75 µm.

it as common. This species is common in the Canadian Arctic Archipelago, and has also been collected in Capitol Reef National Park, Utah (Consortium of Lichen Herbaria 2023).

Psoraceae

***Protoblastenia rupestris* (Scop.) J.Steiner**
Figure 8B

Material examined. CANADA – NUNAVUT/QIKIQTAALUK REGION • Devon Island, Haughton Crater; 75°26′ 20″N, 089°48′07″W; 21.VII.2017; A. Srivastava leg.; DI7; CANL 10027363.

Identification. Thallus pale grey, pale brown, to white, crustose, rimose. Apothecia scattered, without obvious thalline margins, disc orange. Asci 8-spored. Ascospores simple, hyaline, ellipsoid to ovoid. Apothecia K+ red (Nash et al. 2004).

Substrate. Saxicolous on limestone.

Notes. Recorded previously on northeast Devon Island (Barrett and Thomson 1975), Cornwallis, Ellesmere, Baffin, Victoria, and Southampton islands, and the Nunavut mainland (Thomson 1997), this diminutive species is likely under-collected throughout its Arctic range. This species may be confused with *Caloplaca*, however *Protoblastenia*'s thalline apothecial margin is lost in mature specimens and is always present in *Caloplaca*, and *Protoblastenia* possess simple ascospores while the ascospores of *Caloplaca* are polariloc-ular (two-celled with a perforated septum) (Nash et al. 2004). This species has also been collected in Utah (Consortium of Lichen Herbaria 2023).

Rhizocarpaceae

***Rhizocarpon chioneum* (Norman) Th. Fr.**
Figure 8C, 8D

Material examined. CANADA – NUNAVUT/QIKIQTAALUK REGION • Devon Island, Haughton Crater; 75°26′ 20″N, 089°48′07″W; 26.VII.2017; A. Srivastava leg.; DI4; GenBank Accession Number: PP047682; CANL 10027350 • Devon Island, Haughton Crater; 75°26′11″N, 089°48′07″W; 26.VII.2017; A. Srivastava leg.; DI13; GenBank Accession Number: PP047689; CANL 10027343 • same locality; 26.VII.2017; A. Srivastava leg.; DI15; GenBank Accession Number: PP047692; CANL 10027342.

Identification. Thallus white to grey, crustose, rimose. Apothecia scattered, with thalline margins, disc black, fissured, epruinose. Asci 8-spored. Ascospores two-celled, colourless to light brown. Hypothecium K+ red, hymenium I+ blue (Thomson 1997).

Substrate. Saxicolous on limestone.

Notes. This calciphile grows on limestone and other basic rocks across the Canadian Arctic and has been frequently collected on Devon Island (Barret and Thomson 1975; Muc and Bliss 1977), as well as on Cornwallis Island (Sowter 1960; Thomson and Weber 1992) and North Kent, Ellesmere, Baffin, and Victoria islands, and mainland Nunavut (Consortium of Lichen Herbaria 2023). Its distinctive red hypothecium, K+ purple epithecium, and one-septate, soon darkening ascospores set it apart from similar species in the area (Thomson 1967; Thomson 1997). Identification of this species was confirmed with the assistance of ITS DNA barcodes.

***Rhizocarpon geographicum* (L.) DC.**
Figure 8E

Material examined. CANADA – NUNAVUT/QIKIQTAALUK REGION • Devon Island, Haughton Crater; 75°25′ 53″N, 089°47′40″W; 26.VII.2017; A. Srivastava leg.; DI10; GenBank Accession Number: PP047683; CANL 10027349 • Devon Island, Haughton Crater; 75°24′40″N, 089°48′49″W; 29.VII.2017; A. Srivastava leg.; DI23; GenBank Accession Number: PP047678; CANL 10027366.

Identification. Thallus greenish yellow to bright yellow on a black prothallus, crustose, areolate to rimose. Apothecia common, scattered, disc black, epruinose. Asci 8-spored. Ascospores submuriform to muriform, pale green to dark brown. Medulla C+ red, P+ yellow, epihymenium K+ red (Nash et al. 2004).

Substrate. Saxicolous on limestone.

Notes. Common and conspicuous, this species is known from the Truelove Lowlands on northeast Devon Island (Barrett and Thomson 1975) and across Nunavut (Consortium of Lichen Herbaria, 2023). There are many yellow *Rhizocarpon* species present in the Canadian Arctic and beyond, and an unfortunate tendency for collectors to name them all *R. geographicum*. Careful use of existing dichotomous keys – such as in Thomson (1997) and examination of ascospores are critical to accurate identification of this species (Benedict 1988). *Rhizocarpon geographicum* is a common model organism in astrobiology studies and has survived exposure to space on both the BIOPAN (de la Torre, 2010) and EXPOSE-E (Onofri et al. 2012) facilities. This species has also been collected in Utah (Consortium of Lichen Herbaria 2023). Identification

of this species was confirmed with the assistance of ITS DNA barcodes.

Teloschistaceae

***Gyalolechia bracteata* (Hoffm.) A. Massal.**
Figure 8F

Material examined. CANADA – Nunavut/Qikiqtaaluk Region • Devon Island, Haughton Crater; 75°24′44″N, 089°48′45″W; 29.VII.2017; A. Srivastava leg.; DI17; CANL 10027358) • Devon Island, Haughton Crater; 75°24′45″N, 089°48′43″W; 29.VII.2017; A. Srivastava leg.; DI18; CANL 10027356 • Devon Island, Haughton Crater; 75°24′50″N, 089°39′56″W; 1.VIII.2017; A. Srivastava leg.; DI27; GenBank Accession Number: PP047680; CANL 10027360.

Identification. Thallus whitish yellow to yellow or orange, crustose, often eroded. Apothecia common, scattered, yellow orange to orange, with a thalline margin, disc epruinose or pruinose. Asci 8-spored. Ascospores simple, hyaline, ellipsoid. Spot tests negative (Nash et al. 2004).

Substrate. Bryicolous/terricolous.

Notes. Common in the Truelove Lowlands (Barrett and Thomson, 1975), this species has been collected across the Canadian Arctic Arctic as *Fulgensia bracteata* (Hoffm.) Räsänen (Consortium of Lichen Herbaria, 2023), which was transferred by Arup et al. (2013) to *Gyalolechia*. This species is one of three members of the Teloschistaceae tested by de Vera et al. (2004) for viability under simulated space conditions. This species has also been reported in Utah (Consortium of Lichen Herbaria 2023). Identification of this species was confirmed with the assistance of ITS DNA barcoding.

***Rusavskia elegans* (Link) S.Y. Kondr. & Kärnefelt**
Figure 8G

Material examined. CANADA – Nunavut/Qikiqtaaluk Region • Devon Island, Haughton Crater; 75°25′45″N, 089°50′18″W; 21.VII.2017; A. Srivastava leg.; DI3; CANL 10027355 • Devon Island, Haughton Crater; 75°26′11″N, 089°49′06″W; 26.VII.2017; A. Srivastava leg.; DI6; CANL 10027354 • Devon Island, Haughton Crater; 75°26′10″N, 089°49′10″W; 26.VII.2017; A. Srivastava leg.; DI12; CANL 10027346 • Devon Island, Haughton Crater; 75°24′46″N, 089°48′39″W; 29.VII.2017; A. Srivastava leg.; DI20; CANL 10027364 • Devon Island, Haughton Crater; 75°25′17″N, 089°50′11″W; 30.VII.2017; A. Srivastava leg.; DI25; CANL 10027297.

Substrate. Saxicolous on limestone.

Notes. This common, caliciphilous species has been collected numerous times on Devon Island (Barrett and Thomson 1975), and, likely due to its conspicuous nature, has been frequently collected and is reported from throughout the Canadian Arctic Archipelago (Thomson, 1997; Consortium of Lichen Herbaria, 2023). Like *Rhizocarpon geographicum*, this species can survive exposure to space, and was tested on the International Space Station's EXPOSE-E platform (Brandt et al. 2014 – as *Xanthoria elegans* (Link) Th. Fr.). This was the only species collected at FMARS during the Mars 160 mission that was also collected at MDRS.

Verrucariaceae

***Polyblastia hyperborea* Th. Fr.**
Figure 8H

Material examined. CANADA – Nunavut/Qikiqtaaluk Region • Devon Island, Haughton Crater; 75°26′19″N, 089°48′45″W; 26.VII.2017; A. Srivastava leg.; DI9a; CANL 10027352.

Identification. Thallus pale white to apparently absent (endolithic within substrate), crustose. Perithecia common, scattered, partially immersed in substrate, black. Asci 8-spored. Ascospores muriform, hyaline. Spot tests negative (Thomson 1997).

Substrate. Saxicolous on limestone.

Notes. Previously reported from Devon Island (Barrett and Thomson 1975), Savić and Tibell (2012) indicate that the name *Polyblastia hyperborea* is often misapplied; however, the spores of this specimen fit within their description of *P. hyperborea* (29 × 17 µm). Thomson (1997) and Thomson and Weber (1992) report the species from Devon, Cornwallis, Ellesmere, Southampton, Baffin, Bathurst, and Victoria islands, as well as sites on mainland Nunavut. This species has also been reported in Dixie National Forest, Utah (Consortium of Lichen Herbaria 2023).

DISCUSSION

Here we present an annotated checklist of 35 lichen species for the Mars Desert Research Station. This study nearly doubles the number of lichen species reported from MDRS, with 23 species being reported from the station's exploration area for the first time. These include: *Acarospora fuscata*, *A. obpallens, A. socialis, Buellia dispersa, Candelariella aurella, C. citrina, Lecanora* cf. *utahensis,* cf. *Circinaria calcarea, Clavascidium lacinulatum, Dermatocarpon taminium, Gyalolechia desertorum, Lobothallia alphoplaca, Peccania subnigra, Protoparmeliopsis peltata, Psora tuckermanii, Rhizoplaca melanophthalma, Rinodina* cf. *athallina, Rusavskia elegans, Staurothele areolate, Verrucaria bernardinensis*, *Xanthomendoza fallax, Xanthoparmelia* cf. *maricopensis, and X. mexicana,* An additional 13 species reported for the station in 2014 (Sokoloff et al. 2016) were recollected by the Mars 160 mission in 2016: *Acarospora leavittii, A. rosulata, A. squamulosa, A. stapfiana, A. strigata, Buellia abstracta, Candelariella rosulans, Heteroplacidium compactum, Placidium acarosporoides*, *Placidium lachneum*, *Protoparmeliopsis garovaglii, and Xanthomendoza trachyphylla.*

This increase in species discovery is likely due to increased time spent collecting at MDRS; the previous inventory at MDRS took place over 2 weeks (rather than the 80-day duration of the current study). Additionally, there was an exclusive focus on lichens during the Mars 160 Mission; previous inventories also focused on vascular plants and endolithic algae in addition to lichens. Only one species (*Enchylium tenax*) was collected in 2014 but not recollected in 2016. This species dominates in soil crust communities of the Great Basin (St. Clair et al. 1993); so is it likely absent from the 2016 collections by chance.

Comparing the MDRS lichen biota to other similar inventoried sites, five species collected here were also documented in a floristic study of Dakota Sandstone outcrops of the Morrison formation (like MDRS) 500 km northwest in Colorado, including: *Acarospora fuscata*, *Enchylium tenax*, *Lobothallia alphoplaca, Rusavskia elegans*, and *Xanthomendoza trachyphylla* (Anderson 1962). At Zion Canyon, 230 km southwest of MDRS, there are three lichen species in common, *Acarospora strigata*, *Candelariella rosulans, and Lobothallia alphoplaca*, (Rushforth et al. 1982). In the San Rafael Swell, 30 km north of MDRS, Rajvanshi et al. (1998) recorded two terricolous species that are shared with the station's biota: *Gyalolechia desertorum* and *Psora tuckermannii*. In their inventory of the high elevation Aquarius Plateau area, 73 km southwest but still in Wayne County, Leavitt and St. Clair (2008) found 11 species in common with MDRS: A*carospora fuscata, A. strigata, Candelariella rosulans, Circinaria calcarea, Lobothallia alphoplaca*, *Protoparmeliopsis garovaglii*, *P. peltata*, *Rhizoplaca melanophthalma, Rusavskia elegans, Staurothele areolata, and Xanthoparmelia mexicana.*

Notably, our *Dermatocarpon taminium* collections appear to be the second report of this species in Utah – while there are no records of this species for the state on the Consortium of Lichen Herbaria website (Consortium of Lichen Herbaria 2023), Munger et al. (2022) collected it at Fifty Mile Canyon in the nearby Glen Canyon National Recreation Area (approximately 130 km south of MDRS) in 2019. This site, evaluated using a combined morphological and molecular approach to species identification, appears to be the most floristically similar to MDRS, with 15 species in common: *Acarospora strigata*, *A. stapfiana* (agg.), *A. leavittii* (agg.), *Candelariella aurella*, *C. citrina*, *C. rosulans* (agg.), *Circinaria* aff. *calcarea*, *Clavascidium lacinulatum*, *Dermatocarpon taminium*, *Lobothallia alphoplaca*, *Placidium* cf. *acarosporoides*, *Verrucaria bernardinensis*, *Xanthoparmelia maricopensis*, *Xanthomendoza fallax*, and *X. trachyphylla*.

The similarities and differences between the MDRS lichen biota and other nearby sites are likely the result of differing microhabitats and collection priorities. The exploration area around MDRS is primarily desert dominated by Mancos shale and Dakota sandstone, and most lichens collected in 2016 are primarily saxicolous in habit. In comparison, the studies at Zion and on the Aquarius plateau took place in treed habitat and in high elevation subalpine zones respectively, while the Colorado and Glen Canyon studies took place in sandstone habitats similar to the station. While the San Rafael Swell is the closest previously surveyed site, the study by Rajvanshi et al. (1998) focused exclusively on terricolous species, excluding the numerous saxicolous species of MDRS. Altogether, our study of the lichen flora of MDRS adds to our lichen biodiversity knowledge of the station and continues to fill in a geographical gap of sites surveyed for lichens in Wayne County.

The 13 species we report here from the Flashline Mars Arctic are the first collected specifically to understand the lichen biodiversity of Haughton Crater, an internationally known impact site and Martian planetary analog. Cockell et al. (2001) examined micro-oases within the impact structure and found that they were more biodiverse than the surrounding landscape but did not include lichens in their study. Later work (Cockell et al. 2003) found that impact processing at Haughton Crater has created new habitat for microorganisms and birds in an otherwise barren high arctic landscape, suggesting that Haughton Crater could be a uniquely biodiverse site on western Devon Island.

In comparison to other lichen biodiversity studies on Devon Island, Barrett and Thomson (1975) found eight species at the Truelove Lowlands on the northeast coast of the island in common with the biota of FMARS: *Candelariella canadensis, Gyalolechia bracteata, Myriolecis dispersa, Physconia muscigena, Polyblastia hyperborea, Protoblastenia rupestris, Rhizocarpon geographicum, and Rusavskia elegans*. In his later synopsis of the American Arctic microlichens, Thomson (1997) recorded 11 species in common with FMARS: *Candelariella canadensis, Farnoldia hypocrita, Gyalolechia bracteata, Lecanora marginata,*

Lecidella patavina, Myriolecis dispersa, Physconia muscigena, Polyblastia hyperborea, Rhizocarpon chioneum, Rhizocarpon geographicum, and Rusavskia elegans. Only *Diplotomma venustum* was not recorded previously by either study on Devon Island, which prior to this study seems to have only been recorded in Nunavut on Victoria Island (Consortium of Lichen Herbaria 2023).

While we only found one species (the cosmopolitan *Rusavskia elegans)* in common between both MDRS and FMARS, the recent discovery of *Acarospora schleicheri* on Ellesmere Island (McMullin, 2018), a species common in the American Southwest, raises the possibility that additional lichen species might be shared between these two analog sites. A survey of lichen collections on the Consortium of Lichen Herbaria website (2023), shows that 12 of the lichen species we documented at MDRS in Utah have also been previously collected in Nunavut. *Candelariella aurella, C. citrina*, and *Rhizoplaca melanophthalma* have been collected on Devon Island, while *Acarospora fuscata* and *Staurothele areolata* are known from nearby Bathurst Island, and *Enchylium tenax* from floristically similar Cornwallis Island. Conversely, 11 of the lichen species we documented at FMARS have been collected previously in Nunavut, but mostly from alpine areas like the Henry and La Sal mountains; only *Diplotomma venustum, Gyalolechia bracteata*, *Lecidella patavina, and Physconia muscigena* have been collected in habitat similar to MDRS.

Human factors also likely played a role in lichen sampling. The biology team on the Mars 160 Mission included biologists briefed on lichen prospecting and collecting but were not lichenologists by training. The most commonly collected species at each site were conspicuous lichens with coloration that stood out on the local landscape (i.e., white *Acarospora strigata* in Utah and orange *Rusavskia elegans* in Nunavut). Also, the crew on EVA often have to balance multiple competing priorities in addition to any science goals, and EVAs are time-limited to simulate working on the irradiated surface of Mars. With additional training and time on the ground, the same crew would undoubtedly collect additional, overlooked species. The ability of a crew to learn-by-doing is critical to studies in crewed spaceflight, where non-specialists often must complete science-return for an Earthside team. Continued lichen sampling at both stations will aid in field astrobiology training and will add new biodiversity records for these fascinating extreme environments.

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ADDITIONAL INFORMATION

Conflict of interest

The authors declare that no competing interests exist.

Ethical statement

No ethical statement is reported.

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Data availability
All data that support the findings of this study are available in the main text.

REFERENCES

Anderson RA (1962) The lichen flora of the Dakota sandstone in north-central Colorado. The Bryologist 65 (3): 242–261.

Armstrong RA (2017) Adaptation of lichens to extreme conditions. In: Shukla, V., Kumar, S., Kumar, N. (eds) Plant Adaptation Strategies in Changing Environment. Springer, Singapore. 1–27. https://doi.org/10.1007/978-981-10-6744-0_1

Arup U, Søchting U, Frödén, P (2013) A new taxonomy of the family Teloschistaceae. Nordic Journal of Botany 31: 16–083. https://doi.org/10.1111/j.1756-1051.2013.00062.x

Barcenas-Peña A, Leavitt SD, Huang J-P, Grewe F, Lumbsch HT (2018) Phylogenetic study and taxonomic revision of the *Xanthoparmelia mexicana* group, including the description of a new species (Parmeliaceae, Ascomycota). MycoKeys 40: 13–28. https://doi.org/10.3897/mycokeys.40.26724

Benedict JB (1988) Techniques in lichenometry: identifying the yellow *Rhizocarpons*. Arctic and Alpine Research 20 (3): 285–291. https://doi.org/10.2307/1551260

Barret, PE, Thomson JW (1975) Lichens from a high arctic coastal lowland, Devon Island, NWT. The Bryologist 78 (2): 160–167. https://doi.org/10.2307/3242046

Brandt A, de Vera J, Onofri S, Ott S (2015) Viability of the lichen *Xanthoria elegans* and its symbionts after 18 months of space exposure and simulated Mars conditions on the ISS. International Journal of Astrobiology 14 (3): 411–425. https://doi.org/10.1017/S1473550414000214

Brinker SR, Knudsen K (2019) The first confirmed report of *Acarospora bullata* from North America. Opuscula Philolichenum 18: 11–16.

Brodo IM, Sharnoff SD, Sharnoff S (2001) Lichens of North America. Yale University Press, New Haven, Connecticut, USA, 795 pp.

Carter O, Kropp B, Noell N, Hollinger J, Baker G, Tuttle A, St. Clair LL, Leavitt SD (2019) A preliminary checklist of the lichens in Great Basin National Park, Nevada, USA. Evansia 36 (3): 72–91. https://doi.org/10.1639/0747-9859-36.3.72

St. Clair LL, Leavitt SD, Clair SBS, Newberry C, Rosentreter R (2021) Lichen checklist for the Jarbidge wilderness area and adjacent forest service lands in Northeastern Nevada, USA. Evansia 38 (2): 43–59. https://doi.org/10.1639/0747-9859-38.2.43

Clarke JDA, Pain CF, Rupert S (2020) Complex expressions of inverted and exhumed relief in central Utah, and some Martian counterparts. Physical Geography 43 (4): 383–400. https://doi.org/10.1080/02723646.2020.1839161

Clarke JDA, Stoker CR (2011) Concretions in exhumed and inverted channels near Hanksville Utah: implications for Mars. International Journal of Astrobiology 10 (3): 161–175. https://doi.org/10.1017/S1473550411000048

Cockell CS, Lee P, Schuerger AC, Hidalgo L, Jones JA, Stokes MD (2001) Microbiology and vegetation of micro-oases and polar desert, Haughton Impact Crater, Devon Island, Nunavut, Canada. Arctic, Antarctic, and Alpine Research 33 (3): 306–318. https://doi.org/10.1080/15230430.2001.12003435

Cockell CS, Osinski GR, Lee P (2003) The impact crater as a habitat: effects of impact processing of target materials. Astrobiology 3 (1): 181–191. https://doi.org/10.1089/153110703321632507

Consortium of Lichen Herbaria (2023). Consortium of Lichen Herbarium Data Portal.https://lichenportal.org/portal/. Accessed on 2023-12-08.

Culberson CF, Kristinsson H (1970) A standardized method for the identification of lichen products. Journal of Chromatography 46: 85–93.

de La Torre R, Sancho LG, Horneck G, de los Ríos A, Wierzchos J, Olsson-Francis K, Cockell CS, Rettberg P, Berger T, de Vera JPP, Ott S (2010) Survival of lichens and bacteria exposed to outer space conditions - results of the Lithopanspermia experiments. Icarus 208 (2): 735–748. https://doi.org/10.1016/j.icarus.2010.03.010.

de Vera J-P, Horneck G, Rettberg P, Ott S (2004) The potential of the lichen symbiosis to cope with the extreme conditions of outer space II: germination capacity of lichen ascospores in response to simulated space conditions. Advances in Space Research 33 (8): 1236–1243. https://doi.org/10.1016/j.asr.2003.10.035.

Direito SO, Ehrenfreund P, Marees A, Staats M, Foing B, Röling WF (2011) A wide variety of putative extremophiles and large beta-diversity at the Mars Desert Research Station (Utah). International Journal of Astrobiology 10 (3): 191–207. https://doi.org/10.1017/S1473550411000012

Elvebakk A, Øvstedal DO (2009) *Caloplaca trachyphylla* new to Europe from high-arctic steppes of Svalbard. Graphis Scripta 21 (2): 61–64.

Esslinger TL (2021) A cumulative checklist for the lichen-forming, lichenicolous and allied fungi of the continental United States and Canada, Version 24. Opuscula Philolichenum 20: 100–394.

Favero-Longo SE, Sandrone S, Matteucci E, Appolonia L, Piervittori R (2014) Spores of lichen-forming fungi in the

mycoaerosol and their relationships with climate factors. Science of The Total Environment 466: 26–33. https://doi.org/10.1016/j.scitotenv.2013.06.057

Giralt M, Bungartz F, Elix JA (2011) The identity of *Buellia sequax*. Mycological Progress 10: 115–119.

Grieve RA (1988) The Haughton impact structure: summary and synthesis of the results of the HISS project. Meteoritics 23 (3): 249–254. https://doi.org/10.1111/j.1945-5100.1988.tb01288.x

Heiðmarsson S (2003) Molecular study of *Dermatocarpon miniatum* (Verrucariales) and allied taxa. Mycological Research 107 (4): 459–468.

Knightly JP, Clarke JDA, Rupert S, Srivastava A (2018) Summary of field investigations from the Mars 160 analog mission in Utah and Devon Island. In: Proceedings of the 49th Annual Lunar and Planetary Science Conference, The Woodlands, USA, 2,094 pp.

Knudsen K, Lendemer JC (2005) Changes and additions to the North American lichen flora -IV. Mycotaxon 93: 289–296.

Knudsen K, Kocourková J (2009). A taxonomic study of *Polysporina gyrocarpa* and *P. cyclocarpa* (Acarosporaceae) and a new record from Asia of *P. arenacea*. Bibliotheca Lichenologica 100: 199–206.

Knudsen K, Reeb V, Westberg M, Srikantha R, Bhattacharya D (2010) *Acarospora rosulata* in Europe, North America and Asia. The Lichenologist 42 (3): 291–296. https://doi.org/10.1017/S0024282909990715

Knudsen K (2012) Notes on the California lichen flora #4. Bulletin of the California Lichen Society 19 (1): 4–7.

Knudsen K, Lendemer JC, Schultz M, Kocourková J, Sheard JW, Pigniolo A, Wheeler T (2017) Lichen biodiversity and ecology in the San Bernardino and San Jacinto Mountains in southern California (USA). Opuscula Philolichenum 16: 15–138.

Knudsen K, Arcadia, LI, Kocourková J (2019). *Acarospora squamulosa*, the correct name for *A. peliocypha*. Mycotaxon 134 (2): 281–287.

Knudsen K, Hollinger J, Götz A, Hodková E (2021). A new name for a common desert lichen. Bulletin of the California Lichen Society 28 (1): 1–4.

Knudsen K, Kocourková J (2021) The real *Acarospora socialis*. Bulletin of the California Lichen Society 22 (2): 41–46.

Kocourková J, Knudsen K, Tucker S (2012) A checklist of the lichenicolous biota of California. Opuscula Philolichenum 11: 64–103.

Leavitt SD, St. Clair LL (2008) Lichens of the Boulder Mountain Plateau, Wayne County, Utah, USA. Evansia 25 (4): 85–89. https://doi.org/10.1639/0747-9859-25.4.85

Leavitt SD, Fankhauser JD, Leavitt DH, Porter LD, Johnson LA, St. Clair LL (2011) Complex patterns of speciation in cosmopolitan "rock posy" lichens - discovering and delimiting cryptic fungal species in the lichen-forming *Rhizoplaca melanophthalma* species-complex (Lecanoraceae, Ascomycota). Molecular Phylogenetics and Evolution 59 (3): 587–602. https://doi.org/10.1016/j.ympev.2011.03.020

Leavitt SD, Fernández-Mendoza F, Pérez-Ortega S, Sohrabi M, Divakar P, Lumbsch T, St. Clair LL (2013) DNA barcode identification of lichen-forming fungal species in the *Rhizoplaca melanophthalma* species-complex (Lecanorales, Lecanoraceae), including five new species. MycoKeys 7: 1–22. https://doi.org/10.3897/mycokeys.7.4508

Leavitt SD, Newberry CC, Hollinger J, Wright B, St. Clair LL (2018). An integrative perspective into diversity in *Acarospora* (Acarosporaceae, Ascomycota), including a new species from the Great Basin, USA The Bryologist 121 (3): 275–285. https://doi.org/10.1639/0007-2745-121.3.275

Lee P, Osinski GR (2005) The Haughton-Mars Project: overview of science investigations at the Haughton impact structure and surrounding terrains, and relevance to planetary studies. Meteoritics & Planetary Science Archives 40 (12): 1755–1758.

Lendemer JC (2009) Contributions to the lichen flora of Pennsylvania - further new and interesting reports of lichens and lichenicolous Fungi. Evansia 26 (3): 131–141. https://doi.org/10.1639/0747-9859-27.2.47

Lindblom L (2006) *Xanthomendoza galericulata*, a new sorediate lichen species, with notes on similar species in North America. The Bryologist 109 (1): 1–8.

Lutzoni F, Miadlikowska J (2009) Lichens. Current Biology 19 (13): R502–R503.

Magnusson AH (1952) New crustaceous lichen species from North America. Acta Horti Gothoburgensis 19: 31–49.

Manzitto-Tripp EA, Lendemer JC, McCain CM (2022) Most lichens are rare, and degree of rarity is mediated by lichen traits and biotic partners. Diversity and Distributions 28 (9): 1810–1819. https://doi.org/10.1111/ddi.13581

McCune B (1987) Distribution of chemotypes of *Rhizoplaca* in North America. The Bryologist 90 (1): 6–14. https://doi.org/10.2307/3243267

McCune B, Rosentreter R (2007) Biotic soil crust lichens of the Columbia Basin. Monographs in North American Lichenology. 1. Northwest Lichenologists, Covallis, Oregon, USA, 105 pp.

McMullin RT (2018) New and interesting lichens and allied fungi from British Columbia, Nova Scotia, Nunavut, Ontario, Prince Edward Island, and Quebec, Canada. Opuscula Philolichenum 17: 275–292.

Meeßen J, Wuthenow P, Schille P, Rabbow E, de Vera JP, Ott S (2015) Resistance of the lichen *Buellia frigida* to simulated space conditions during the preflight tests for BIOMEX—viability assay and morphological stability. Astrobiology 15 (8): 601–615. https://doi.org/10.1089/ast.2015.1281

Munger IA, Baugh M, Henrie JR, Hollinger J, Crepeau R, Leavitt SD (2022) Integrative biodiversity inventories: characterizing lichen-forming fungal diversity in Glen Canyon National Recreation Area using DNA barcoding and vouchered specimens. Western North American Naturalist 82 (2): 213–233. https://doi.org/10.3398/064.082.0201

Nash III T, Ryan BD, Gries C, Bungartz F (2002) Lichen flora of the Greater Sonoran Desert Region, Volume 1. Lichens Unlimited, Arizona State University, Tempe, Arizona, USA, 532 pp.

Nash III T, Ryan BD, Diederich P, Gries C, Bungartz F (2004) Lichen flora of the Greater Sonoran Desert Region, Volume 2. Lichens Unlimited, Arizona State University, Tempe, Arizona, USA, 742 pp.

Nash III T, Gries C, Bungartz F (2007) Lichen flora of the Greater Sonoran Desert Region, Volume 3. Lichens Unlimited, Arizona State University, Tempe, Arizona, USA, 567 pp.

Newberry CC, St. Clair LL (1991) Additions to the lichen flora of Utah I. The Bryologist 94 (2): 154–156. https://doi.org/10.2307/3243690

Nordin A (2000) Taxonomy and phylogeny of *Buellia* species with pluriseptate spores (Lecanorales, Ascomycotina). Acta Universitatis Upsaliensis, Symbolae Botanicae Upsalienses 33 (1): 1–117.

Nurtai L, Knudsen K, Abbas A (2017) A new species of the *Acarospora strigata* group (Acarosporaceae) from China. The Bryologist 120 (4): 382–387. https://doi.org/10.1639/0007-2745-120.4.382

Oliveira MF, Maciel-Silva AS (2022) Biological soil crusts and how they might colonize other worlds: insights from these Brazilian ecosystem engineers. Journal of Experimental Botany 73 (13): 4362–4379. https://doi.org/10.1093/jxb/erac162

Onofri S, Noetzel R, de Vera JP, Ott S, Zucconi L, Selbmann L, Scalzi G, Venkateswaran K, Rabbow E, Sánchez F, Horneck G (2012). Survival of rock-colonizing organisms after 1.5 years in Outer Space. Astrobiology 12: 508–16. https://doi.org/10.1089/ast.2011.0736

Orange A, James PW, White FJ (2001) Microchemical methods for the identification of lichens. British Lichen Society, London, United Kingdom, 101 pp.

Osburg J (2003) Crew experience at the Mars Desert Research Station. In: International Conference on Environmental Systems, Vancouver, Canada. SAE Technical Paper 2003-01-2390, 2 pp. https://doi.org/10.4271/2003-01-2390

Osinski GR, Spray JG, Lee P (2005) Geological map of the Haughton impact structure, Devon Island, Nunavut, Canada. Supplement to Meteoritics & Planetary Science 40 (12) 1789–1812.

Owe-Larsson B, Nordin A, Tibell L, Sohrabi M (2011) *Circinaria arida* sp. nova and the '*Aspicilia desertorum*' complex. Bibliotheca Lichenologica 106: 235–246.

Paukov AG, Davydov EA, Nordin A, Roux C, Şenkardeşler A, Sohrabi M, Vondrák J, Frolov IV, Teptina AY, Shiryaeva AS (2019) Three new species, new combinations and a key to known species of *Lobothallia* (Megasporaceae). The Lichenologist 51 (4): 301–322. https://doi.org/10.1017/S0024282919000264

Petersen F (1980) Sedimentology of the uranium-bearing Salt Wash Member and Tidwell unit of the Morrison Formation in the Henry and Kaiparowits Basins, Utah. Henry Mountains Symposium 1980, Utah Geology Association. Salt Lake City, USA, 305–322 pp.

Rajvanshi V, St. Clair LL, Webb B, Newberry CC (1998) The terricolous lichen flora of the San Rafael Swell, Emery County, Utah, USA In: Glenn M, Harris R, Dirig R, Cole M (Eds) Lichenographia Thomsoniana: North American Lichenology in Honor of John W. Thomson. Mycotaxon, Ithaca, New York, USA, 399–406 pp.

Ratnasingham S, Hebert, PD (2007) BOLD: The Barcode of Life Data System (http://www. barcodinglife.org). Molecular Ecology Notes 7 (3): 355–364. https://doi.org/10.1111/j.1471-8286.2007.01678.x

Rosentreter R, Bowker M, Belnap J (2007) A field guide to biological soil crusts of Western U.S. Drylands. U.S. Government Printing Office, Denver, Colorado, USA, 103 pp.

Rushforth SR, St. Clair LL, Brotherson JD and Nebeker GT (1982) Lichen community structure in Zion National Park. The Bryologist 85 (2): 185–192. https://doi.org/10.2307/3243001

Sancho LG, De la Torre R, Horneck G, Ascaso C, de los Rios A, Pintado A, Wierzchos J. Schuster M (2007) Lichens survive in space: results from the 2005 LICHENS experiment. Astrobiology 7 (3): 443–454. https://doi.org/10.1089/ast.2006.0046

Savić S, Tibell L (2012) *Polyblastia* in northern Europe and the adjacent Arctic. Symbolae Botanicae Upsalienses 36: 1, 77 pp.

Schofield WB, Cody WJ (1955) Botanical investigations on coastal southern Cornwallis Island, Franklin District, N.W.T. The Canadian Field-Naturalist 69 (3): 116–128.

Selva SB (2003) Using calicioid lichens and fungi to assess ecological continuity in the Acadian Forest Ecoregion of the Canadian Maritimes. The Forestry Chronicle 79 (3): 550–558. https://doi.org/10.5558/tfc79550-3

Sheard JW (2018) A synopsis and new key to the species of *Rinodina* (Ach.) Gray (Physciaceae, lichenized Ascomycetes) presently recognized in North America. Herzogia 31 (p1): 395–423. https://doi.org/10.13158/heia.31.1.2018.395

Sokoloff PC, Freebury CE, Hamilton PB, Saarela JM (2016) The "Martian" flora: new collections of vascular plants, lichens, fungi, algae, and cyanobacteria from the Mars Desert Research Station, Utah. Biodiversity Data Journal 4: e8176. https://doi.org/10.3897/BDJ.4.e8176

Sokoloff PC, Murray DA, McBeth SR, Irvine MG, Rupert SM (2020) Additions to the "Martian Flora": new botanical records from the Mars Desert Research Station, Utah. Biodiversity Data Journal 8: e55063. https://doi.org/10.3897/BDJ.8.e55063

Sowter FA (1960) The lichens of Cornwallis Island, NWT. Revue bryologique et lichenologique 60: 120–123.

St. Clair LL, Newberry CC, Nebeker GT (1991) Catalog of the lichens of Utah. Mycotaxon 40: 199–264.

St. Clair LL, Johansen JR, Rushforth SR (1993) Lichens of soil crust communities in the intermountain area of the western United States. The Great Basin Naturalist 53 (1): 5–12.

St. Clair LL, Newberry CC, Yearsley KH (1995) Additions, corrections, and notes on the lichen flora of Utah. The Bryologist 98 (1): 146–148. https://doi.org/10.2307/3243651

Thomson JW (1967) Notes on *Rhizocarpon* in the Arctic. Nova Hedwigia 14: 421–483.

Thomson JW, Weber WA (1992) Lichens collected on the Arctic excursion of the 9th International Botanical Congress (Montreal) in 1959. The Bryologist 95 (4): 392–405. https://doi.org/10.2307/3243563

Thomson JW (1984) American Arctic Lichens. 1. The Macrolichens. The University of Wisconsin Press, Madison, Wisconsin, USA, 504 pp.

Thomson JW (1997) American Arctic Lichens. 2. The Microlichens. The University of Wisconsin Press, Madison, Wisconsin, USA, 675 pp.

Timdal E (1986) A revision of *Psora* (Lecideaceae) in North America. The Bryologist 89 (4): 253–275. https://doi.org/10.2307/3243197

Ulicny D (2009) Sequence stratigraphy of the Dakota Formation (Cenomanian), southern Utah: interplay of eustasy and tectonics in a foreland basin. Sedimentology 46: 807–836.

Westberg M (2007) *Candelariella* (Candelariaceae) in Western United States and Northern Mexico: The 8-spored, Lecanorine Species. The Bryologist 110 (3): 391–419. https://doi.org/10.1639/0007-2745(2007)110[391:CCIWUS]2.0.CO;2

Westberg M (2010) The identity of *Candelariella canadensis*. The Lichenologist 42 (1): 119–122. https://doi.org/10.1017/S0024282909990272

Westberg M, Morse CA, Wedin M (2011) Two new species of *Candelariella* and a key to the Candelariales (lichenized Ascomycetes) in North America. The Bryologist 114 (2): 325–334. https://doi.org/10.1639/0007-2745-114.2.325

Yearsley K, St. Clair LL, Newberry, CC (1998) Corticolous lichens of Capitol Reef National Park and adjacent areas of Fishlake National Forest, Utah, USA In: Glenn M, Harris R, Dirig R, Cole M (Eds) Lichenographia Thomsoniana: North American Lichenology in Honor of John W. Thomson. Mycotaxon, Ithaca, New York, USA, 315–322 pp.